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**THE SILVICULTURE
OF
INDIAN TREES**

VOLUME I

Dilleniaceae to Leguminosae (Papilionaceae)

OXFORD UNIVERSITY PRESS

LONDON EDINBURGH GLASGOW NEW YORK

TORONTO MELBOURNE CAPE TOWN BOMBAY

HUMPHREY MILFORD

PUBLISHER TO THE UNIVERSITY

THE SILVICULTURE OF INDIAN TREES

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VOLUME I

Dilleniaceae to Leguminosae (Papilionaceae)

PUBLISHED UNDER THE AUTHORITY OF HIS MAJESTY'S

SECRETARY OF STATE FOR INDIA IN COUNCIL

OXFORD

AT THE CLARENDON PRESS

1921

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INTRODUCTION

SCOPE OF PRESENT WORK. This work is the outcome of several years of research into silvicultural problems at the Forest Research Institute, Dehra Dun, and at outlying experimental stations, combined with observations recorded in many parts of India and Burma for a period extending over more than twenty years. My original intention was to publish, in the form of detached notes, only the results of my own investigations, confining my attention to a limited number of the more important forest trees. I was soon convinced, however, that a more useful purpose would be served by including all trees, whether of special importance or not, which have received even slight study from a silvicultural point of view, adding to the results of my own investigations those recorded from time to time by others. Such a course will enable future workers who may undertake the study of any particular species of tree to ascertain what information is already available regarding it and to pursue their investigations along fresh lines. The importance of silvicultural research is now more fully realized in India than it was at one time, and in future years great development in research methods and in our knowledge of the various trees may be anticipated. In a vast country like India, with an infinite variety of climates and forest types and a rich array of tree species, the different species cannot be studied fully except in their own habitat, for which purpose decentralization of work will be essential before any appreciable progress is made. From this point of view the present work may be regarded as nothing more than an attempt to pave the way for such research, or in other words as merely a foundation on which a more substantial edifice may be gradually built by future workers.

As the title indicates, this work deals with the trees of India mainly from a silvicultural point of view. Exception may therefore be taken to the inclusion of botanical descriptions and drawings of the seedlings of many of the species. The importance of the seedling, as marking the most critical stage in the life of the tree, will be emphasized later. Meanwhile it may be mentioned that one of the chief difficulties experienced at present in studying the reproduction of forest trees is the fact that the seedlings of many of the species are difficult to recognize in all their stages. In course of time a more or less complete botanical study of the seedlings will no doubt be made, and a critical systematic account of them will then be possible. It is doubtful, however, if this will be accomplished for a long time to come; meanwhile it is considered advisable to include in the present work drawings and descriptions of those seedlings which have already been studied, since these comprise the greater proportion of the more important forest tree seedlings the identification of which is essential if any marked progress is to be made in the study of the trees in question. The descriptions have been made either from seedlings raised artificially or from natural seedlings collected in the forest; with

very few exceptions they have been made from fresh, and not from dried specimens. The drawings have been executed by the artists of the Forest Research Institute at Dehra Dun, under my supervision. It should be mentioned that seedlings exhibit great differences, due to the conditions under which they are grown, in the dimensions of their leaves, stems, and other parts, and it is therefore difficult to give dimensions with any degree of accuracy; the dimensions given in the descriptions are taken from actual specimens examined, but they should not be regarded as defining absolutely the sizes of leaves and other parts of seedlings grown under all conditions.

Although this work deals primarily with forest trees of the Indo-Burmese region, a certain number of exotics have also been included, more particularly those, such as *Eucalyptus* spp., which are already grown to some extent in plantations or are otherwise of some interest. Indian species regarding which nothing is known silviculturally have as a rule been omitted altogether. The arrangement of genera and species according to botanical natural orders, which is adopted in the present work, is to a great extent logical from a silvicultural point of view, for botanically allied species often exhibit silvicultural affinities in a marked degree.

CONDUCT OF SILVICULTURAL RESEARCH AT DEHRA DUN AND ELSEWHERE. A preliminary study of the factors affecting the reproduction of trees and the growth and survival of seedlings was carried out by means of experimental plots at Dehra Dun, where over 2,000 such plots were under observation at one time or another; some of the Himalayan species were subsequently studied in experimental plots at Simla at an altitude of 7,000 ft. Control plots were also maintained and kept under observation in various forest tracts with the view of supplementing the preliminary plots at Dehra Dun. The preliminary experimental plots were designed for the most part with the object of ascertaining for each species the factors which affect germination, particularly under natural conditions, and those which influence the development and survival of the seedling; such factors include temperature, moisture, light, soil-texture, soil-covering, &c., as well as animals, birds, and insects. In connexion with these preliminary experimental plots it must be emphasized that although useful, indeed essential, for the close study of the factors bearing on reproduction and other questions, they cannot be regarded as the sole basis for general conclusions. The latter can be formed only after further close study in the forest under the varying conditions met with in different localities: in connexion with such further study, however, the preliminary experimental plots have proved invaluable. Although Dehra Dun is no doubt a favourable centre for the preliminary study of a large number of Indian species, and although I have in some respects had exceptional opportunities for studying the habits of forest trees in many different localities, still local conditions vary to such an extent, even within comparatively narrow limits, that there is always scope for further study on the spot; this will, it is hoped, dispel any idea that finality is claimed for the results recorded in this work, and that there is not abundant scope for further local study even in the case of those trees which have been somewhat fully dealt with.

It may be of interest to describe briefly the forest vegetation and climatic

conditions at or in the neighbourhood of Dehra Dun, where most of the preliminary experimental plots were established. Situated in a valley between the outer ranges of the Himalaya and the outlying Siwalik hills, at an elevation of about 2,200 ft., with a comparatively heavy rainfall, Dehra Dun forms in many respects an admirable centre for the conduct of experimental work dealing with species differing widely in geographical distribution and climatic range. The surrounding forests are composed largely of sal (*Shorea robusta*), with many of the miscellaneous species found in the Indian Peninsula, north-eastern India, or Burma, among which are the following :

Anonaceae, *Miliusa velutina* ; Malvaceae, *Kydia calycina*, *Bombax malabaricum* ; Sterculiaceae, *Sterculia villosa*, *Pterospermum acerifolium* ; Rutaceae, *Aegle Marmelos* ; Burseraceae, *Garuga pinnata* ; Meliaceae, *Cedrela Toona* ; Rhamnaceae, *Zizyphus Jujuba*, *Z. Xylopyrus* ; Sapindaceae, *Schleichera trijuga* ; Anacardiaceae, *Buchanania latifolia*, *Semecarpus Anacardium*, *Mangifera indica* (probably escaped from cultivation), *Odina Wodier*, *Spondias mangifera* ; Leguminosae, *Dalbergia Sissoo*, *Ougeinia dalbergioides*, *Erythrina suberosa*, *Butea frondosa*, *Cassia Fistula*, *Bauhinia racemosa*, *B. malabarica*, *B. purpurea*, *B. variegata*, *Acacia Catechu*, *Albizzia odoratissima*, *A. procera*, *A. stipulata* ; Rhizophoraceae, *Carallia lucida* ; Combretaceae, *Terminalia belerica*, *T. Chebula*, *T. tomentosa*, *Anogeissus latifolia* ; Myrtaceae, *Eugenia Jambolana*, *E. operculata*, *Careya arborea* ; Lythraceae, *Lagerstroemia parviflora* ; Samydaceae, *Casearia glomerata*, *C. tomentosa* ; Rubiaceae, *Adina cordifolia*, *Stephegyne diversifolia*, *Hymenodictyon excelsum* ; Ebenaceae, *Diospyros Embryopteris* ; Apocynaceae, *Carissa spinarum*, *Alstonia scholaris*, *Holarrhena antidysenterica*, *Wrightia tomentosa* ; Boraginaceae, *Cordia Myxa*, *Ehretia laevis* ; Bignoniaceae, *Oroxylum indicum*, *Stereospermum suaveolens* ; Verbenaceae, *Gmelina arborea* ; Lauraceae, *Litsaea sebifera*, *L. polyantha* ; Euphorbiaceae, *Bridelia retusa*, *Phyllanthus Emblica*, *Bischofia javanica*, *Trewia nudiflora*, *Mallotus philippinensis* ; Ulmaceae, *Holoptelea integrifolia* ; Moraceae, *Ficus bengalensis*, *F. Rumphii*, *F. Cunia*, *F. glomerata*, and other species ; Salicaceae, *Salix tetrasperma*.

The typical sub-Himalayan species *Dalbergia Sissoo* is abundant in riverain tracts. Certain species usually characteristic of tropical forest, for instance *Carallia lucida* and *Calamus tenuis*, occur naturally in swampy localities in the neighbourhood of Dehra Dun. On the other hand, certain Himalayan species which ascend to 6,000 ft. or more also occur naturally in the Dehra Dun valley, for instance *Pyrus Pashia*, *Ficus palmata*, and in swampy localities *Acer oblongum*, *Quercus incana*, and *Celtis australis*. Certain trees of the temperate Himalaya have been planted at Dehra Dun ; *Cupressus torulosa* and *Quercus incana* grow well, the latter regenerating naturally with freedom, while the deodar and blue pine grow fairly well for a time, though they do not attain large dimensions and fail to ripen their seed. *Pinus longifolia* flourishes, growing rapidly and regenerating naturally where conditions are favourable. At the same time many trees of the warmer regions thrive fairly well when introduced, for instance *Dillenia indica*, *Lagerstroemia Flos-Reginae*, *Albizzia lucida*, *Tectona grandis*, *Sterculia alata*, *Mimusops Elengi*, *Amoora Rohituka*, *Saraca indica*, *Michelia Champaca*, *Dalbergia latifolia*, and others, while among Burmese trees *Xylia dolabriformis*, *Dalbergia cultrata*, *D. Oliveri*, and *Lager-*

stroemia tomentosa have recently been introduced and show some promise. The more tender tropical trees, however, do not survive the winter cold at Dehra Dun. Meteorological statistics show that the normal rainfall at Dehra Dun observatory, the mean of 33 years, is 85·22 in., distributed as follows

January . . .	2·27	July . . .	27·00
February . . .	2·33	August . . .	30·55
March . . .	0·98	September . . .	9·43
April . . .	0·70	October . . .	0·89
May . . .	1·48	November . . .	0·30
June . . .	8·42	December . . .	0·87

This shows the monsoon climate typical of India as a whole, the great bulk of the rain falling during the period of the south-west monsoon. The following shade temperatures recorded at Dehra Dun prior to 1903 may also be quoted

Absolute maximum	111·0° F.
Absolute minimum	33·9° F.
Highest mean monthly maximum for year . . .	95·0° F.
Lowest mean monthly minimum for year . . .	44·8° F.
Highest mean daily maximum for year . . .	97·0° F.
Lowest mean daily minimum for year . . .	44·4° F.

Such is the locality in which most of the preliminary investigations in conditions affecting the reproduction and early life-history of the trees dealt with in this work were carried out. The species of the temperate Himalayas, however, form an important exception; these were studied in detail in their own habitat. The more tender tropical species, again, have for the most part not yet been studied in any detail.

CLIMATE OF INDIA. An appreciation of the climatic conditions prevailing in India is of such importance in connexion with the study of the various forest types met with and of their component species, that a brief sketch of these conditions will not be out of place before we proceed to a consideration of the chief forest types.

The climatic conditions of India probably show more variation than those of any other tract of similar area in the world. The normal rainfall varies from less than 3 inches a year in upper Sind to 460 inches at Cherrapunji in the Assam hills and over 300 inches in exposed positions at the top of the Western Ghats and in the hills of Arakan and Tenasserim. Actually a rainfall of 905 inches was recorded at Cherrapunji in the year 1861, while in upper Sind years have been recorded during which no rain fell.

The rainfall of India is governed mainly by the monsoons, of which there are two, the south-west or wet monsoon and the north-east or dry monsoon: of the two the former is by far the more important, bringing as it does about 90 per cent. of the rainfall. Owing to the influence of the monsoon the year may, throughout the greater part of India, be divided into a wet season from May–June to September–October and a dry season throughout

¹ Gilbert T. Walker, Monthly and Annual Rainfall Normals, Mem. Ind. Met. Dept. vol. **xxii**, pt. i, 1913.

² Sir John Eliot, Normal Monthly and Annual Means of Temperature, &c., *ibid.* vol. **xvii**, 1904.

the rest of the year. The south-west monsoon, starting from the south and bringing moisture-laden air currents from the Indian Ocean and Arabian Sea, is diverted owing to the rotation of the earth and strikes the coasts of India and Burma from a south-westerly direction. The monsoon proper lasts from June to September, during which period almost general rain falls throughout the greater part of India. The period from October to December, during which the humid currents pass out of the Indian region to the equatorial belt, is known as the retreating monsoon period. November and December are characterized by fine weather, clear skies, a large diurnal range of temperature, and low humidity, but during these two months cyclonic storms sometimes give rainfall in the Deccan and southern Madras coast districts, particularly along the Coromandel coast, and also produce occasional heavy rain in the Nilgiris. By the beginning of January the north-east monsoon is fully established over the Indian region. The dry winds of this monsoon blow from a general north-easterly direction ; they bring regular rainfall only when they pass over the Bay of Bengal and acquire humidity, which they deposit in the form of rain over the south-eastern portion of the Indian Peninsula. During the cold season the rainfall is greatest in the submontane districts of northern India ; it decreases away from the hills and is negligible over the greater part of the Peninsula and in Lower Burma. The cold season, however, is in many localities characterized by heavy night dews, which exercise a beneficial effect on vegetation. The chief feature of the cold weather precipitations is the heavy snowfall which takes place in the higher ranges of the Himalaya, increasing in amount with elevation. The second half of the dry season includes the months of March, April, and May, which are characterized by high temperatures and an absence of rain, except for occasional storms of a local nature, sometimes accompanied by hail : in Burma the second half of May is characterized by frequent and often heavy showers of rain preceding the monsoon proper.

The rainfall map gives a clear picture of the effects of the monsoon currents. The regions of heaviest rainfall coincide with the occurrence of hill ranges which intercept the moisture-laden currents. The dry Deccan districts, over which the currents pass after depositing the greater part of their moisture on the Western Ghats, have for the most part a rainfall of less than 30 inches. A similar dry region, where the rainfall is less than 40 inches and in places is not much over 20 inches, is the dry zone occupying the central and southern part of Upper Burma : here the forest vegetation bears a similarity to that of the dry Peninsular region.

The rainfall is closely connected with atmospheric humidity. In some of the coastal and hill regions the rainy season is characterized by excessive humidity, amounting almost to supersaturation, while in the drier regions, during the hottest part of the dry season the atmospheric dryness is so excessive that the usual methods employed in calculating the humidity have failed.

So far as forest vegetation is concerned the dry hot-weather months are in some respects critical ones, in that they mark the season of forest fires, which exercise a considerable influence on the constitution and type of the crop by encouraging fire-resisting species at the expense of the more sensitive

species. Trying though the hot season is, the vegetation nevertheless adapts itself to this annual period of heat and drought, the great majority of the deciduous trees shedding their leaves early in the season and remaining leafless during a part or the whole of it. Of greater importance is the rainy season, for it is the season which governs the rainfall, and therefore exercises a predominating influence on the broad classification of climatic forest formations in India. Damage to forests by abnormal drought, which in certain years takes place on an extensive scale, is due not to conditions prevailing in the regular hot weather months, but to failure of the monsoon rains.

Temperature is another important factor which, in conjunction with rainfall and atmospheric humidity, determines the character of the forest vegetation. Temperature readings by the Meteorological Department of India are taken under conditions as far as possible similar : the thermometers are placed with their bulbs 4 ft. above ground in open sheds where free circulation of air is permitted, the sheds being covered with a thick roof. The temperature figures in this work, which are quoted from the Indian Meteorological Memoirs, are the absolute maximum and minimum shade temperatures measured in this way prior to 1903. These absolute figures give a clearer indication of the extremes which the various species have to encounter in their natural habitat than figures showing average monthly or annual means of maximum and minimum temperatures would give. It should be noted, however, that these absolute temperatures are measured under cover, and do not represent either the actual maximum to which the plants are exposed during the day, taking into account the direct heat of the sun and the heat reflected from the ground, or the actual minimum to which they are exposed at night when loss of heat by radiation is taken into consideration. Thus the absolute minimum temperature quoted is frequently well above freezing-point in the case of species which are known to occur in localities subject to annual frost. For comparative purposes, however, the absolute maximum and minimum shade temperatures as recorded by the Meteorological Department are of much greater value than temperature figures recorded under different conditions of insolation, radiation, and other factors.

The diurnal and annual ranges of temperature are of some importance in regulating the distribution of species. The diurnal range is affected chiefly by the presence of clouds and by the humidity. It is much greater in the dry than in the wet season, being usually greatest in November ; it is least on the coast and increases on proceeding inland, reaching a maximum in the dry regions of the Punjab and upper Sind. The annual range is likewise smallest in the coast districts and greatest in regions far from the sea and in the driest districts.

As might be expected in a country possessing the loftiest mountain range in the world, the effect of altitude on the temperature, and consequently on the vegetation, is probably better illustrated in India than in almost any other portion of the globe. Thus the Himalayan range exhibits climatic regions ranging from tropical through sub-tropical, warm and cool temperate, to alpine and arctic, and the changes in the forest flora are marked by well-defined zones of altitude. The other mountain regions of India exhibit these changes on a somewhat more restricted scale.

BRIEF SKETCH OF THE FOREST VEGETATION OF INDIA. From a silvicultural or oecological point of view a mere description of the various types of forest met with in any region is in itself of small interest compared with a study of the factors which on the one hand affect their general distribution and on the other determine their origin in and their occupancy of any given locality. Consideration of these complex factors, however, will be much facilitated if we commence with a brief sketch of the forest vegetation of India, largely from a floristic point of view. In such a sketch it will be impossible to do more than give a rough idea of the main types of forest met with, and this can be done most conveniently according to geographical regions determined as far as possible by the character of the forest flora. For our purpose it will be convenient to recognize twelve different regions, namely, (1) the western Himalayan region, (2) the eastern Himalayan region, (3) the trans-Indus region, (4) the north-western dry region, (5) the Gangetic plain, (6) the west coast region, (7) the central Indian region, (8) the Deccan and Carnatic, (9) Assam, (10) Chittagong and Arakan, (11) Burma, (12) the Andamans.

1. *The western Himalayan region.* This region comprises the sub-Himalayan tract and the Himalayan range from Kumaun to Chitral. It is characterized by a rainfall varying for the most part from 40 to 80 in., though in some parts of the submontane tracts it reaches 100 in. or more, while in the inner valleys and towards the north-west frontier the climate is dry or even arid. This region is divisible into three zones of altitude: (a) the submontane zone and lower hills, up to about 5,000 ft.; (b) the temperate zone, from about 5,000 to 11,000–12,000 ft.; (c) the alpine zone, from 11,000–12,000 ft. up to about 15,000 ft.

(a) The submontane tract contains an almost continuous belt of sal forest running, with occasional breaks, throughout the eastern portion of the tract as far west as the Jumna, and to a very small extent beyond; details of this sal belt, which extends into the sub-Himalayan valleys and ascends the outer hills in places, will be found under *Shorea robusta*. The sal belt is broken at intervals by savannah lands with scattered trees, chiefly *Butea frondosa* and *Bombax malabaricum*, or by different types of forest, for instance (i) riverain forests of *Acacia Catechu* and *Dalbergia Sissoo* (described under these species); (ii) swamp forests of *Eugenia Jambolana*, *Diospyros Embryopteris*, *Albizzia procera*, *Ficus glomerata*, *Bischofia javanica*, *Pterospermum cerifolium*, *Cedrela Toona*, *Celtis australis*, *Treivia nudiflora*, *Putranjiva Roxburghii*, *Salix tetrasperma*, and other trees, with the cane *Calamus tenuis*; (iii) dry thorn forests of *Zizyphus Jujuba*, *Z. Xylopyrus*, *Acacia Catechu*, and others; (iv) mixed deciduous forests containing *Terminalia* spp., *Bombax malabaricum*, *Lagerstroemia parviflora*, *Anogeissus latifolia*, *Stereospermum suaveolens*, *Phyllanthus Emblica*, *Adina cordifolia*, *Ougeinia dalbergioides*, *Odina Wodier*, *Hymenodictyon excelsum*, *Holoptelea integrifolia*, *Cassia Fistula*, and many other species. These mixed forests ascend the outer hills to between 3,000 and 4,000 ft., the bamboo *Dendrocalamus strictus* occurring in great abundance in places on the lower slopes. As the elevation increases new species such as *Bauhinia retusa*, *Sapium insigne*, *Engelhardtia spicata*, *Boehmeria rugulosa*, *Pistacia integerrima*, and *Euphorbia Royleana* make their appearance, while some of the trees of the lower elevations are no longer found: finally *Pinus longifolia* appears, at first

scattered among other species but soon forming extensive pure forests towards the upper limit of this zone. In the western part of this region, in the Jhelum and Rawalpindi districts and in the North West Frontier Province, the forest becomes drier in character, the prevailing species in the submontane tracts and outer hills being *Acacia modesta*, *Olea cuspidata*, *Carissa spinarum*, *Dodonaea viscosa*, and other xerophytic species.

(b) The temperate zone, which begins at about 5,000 ft. and ascends to 11,000–12,000 ft., contains extensive forests of conifers and broad-leaved trees. Of the former *Pinus longifolia* enters the zone, but is confined to the lower elevations and soon gives place to deodar (*Cedrus Deodara*) and blue pine (*Pinus excelsa*), while higher up spruce (*Picea Morinda*) and silver fir (*Abies Pindrow*) make their appearance and form forests of large extent, mainly between 8,000 and 11,000 ft.; of other conifers the yew (*Taxus baccata*) is common in some localities, while the cypress (*Cupressus torulosa*) is found locally, and the edible pine (*Pinus Gerardiana*) occurs in the inner dry valleys. The broad-leaved trees comprise oaks, of which *Quercus incana*, *Q. dilatata*, and *Q. semecarpifolia* are the chief, with *Q. Ilex* in the drier valleys, maples, horse-chestnut (*Aesculus indica*), poplar (*Populus ciliata*), elm (*Ulmus Wallichiana* being the chief), alder (*Alnus nepalensis* and *A. nitida*, the latter descending below the zone), birch (*Betula alnoides*), *Cornus*, *Prunus Padus*, *Rhododendron arboreum*, and other trees.

(c) The alpine zone extends from 11,000–12,000 ft. up to about 15,000 ft. or sometimes higher. The characteristic trees are the high-level silver fir, the silver birch (*Betula utilis*), and junipers. Rhododendrons are far less numerous than in the eastern Himalaya, and are represented by three shrubby species.

2. *The eastern Himalayan region.* This region, extending from Sikkim eastwards, embraces the most humid portion of the Himalayan range. Nepal, owing to want of knowledge of its forest flora, constitutes a gap between the western and eastern regions as here defined. The eastern region may be divided into three zones of altitude: (a) the tropical zone, up to about 5,000 ft.; (b) the temperate zone, from 5,000 to 12,000 ft.; and (c) the alpine zone, from 12,000 to 16,000 ft.

(a) The tropical zone begins with a forest belt stretching some distance out into the plains and consisting of several different types of forest, the chief of which are (i) sal forests, described in some detail under *Shorea robusta*, and including the sal savannah tracts, in which the dominant grass is *Saccharum Narenga*; (ii) riverain forests of *Dalbergia Sissoo* and *Acacia Catechu*; (iii) mixed deciduous forests of *Terminalia* spp., *Lagerstroemia parviflora*, *Sterculia villosa*, *Bombax malabaricum*, *Duabanga sonneratioides*, *Anthocephalus Cadamba*, *Schima Wallichii*, *Gmelina arborea*, *Cedrela Toona*, *Albizia procera*, *Premna*, *Bauhinia*, *Stereospermum*, &c.; (iv) moist savannah forests, consisting of stretches of tall savannah grasses, of which *Saccharum procerum* is among the commonest, with scattered trees, among the chief of which are *Albizia procera*, *Bombax malabaricum*, and *Bischofia javanica*; (v) evergreen forests with a large number of species, among which are *Michelia Champaca*, *Schima Wallichii*, *Artocarpus Chaplasha*, *Dillenia indica*, *Talauma Hodgsoni*, *Aesculus punduana*, *Amoora*, *Eugenia*, *Echinocarpus*, *Eurya*, *Garcinia*, *Elaeocarpus*, *Cinnamomum Cecidodaphne*, *Canarium sikkimense*, and *Ficus elastica*, the last

named now rare ; there are numerous canes, climbers and evergreen shrubs forming a dense impenetrable undergrowth.

In the outer hills sal, where present, occurs chiefly on the ridges, the intervening depressions and valleys being occupied by moist mixed forest in which the bamboo *Dendrocalamus Hamiltonii* is often abundant. In the upper part of this zone two characteristic trees, *Betula cylindrostachys* and *Alnus nepalensis*, make their appearance.

(b) The temperate zone, from 5,000 to 12,000 ft., may be divided into two belts : (i) the lower belt below 9,000 ft., containing a large number of different broad-leaved species, including *Quercus lamellosa*, *Q. lineata*, *Q. pachyphylla*, and other oaks, *Castanopsis*, *Michelia excelsa* and other Magnoliaceae, *Bucklandia populnea*, *Cedrela*, many laurels and maples, alder, birch, *Pyrus*, *Symplocos*, *Echinocarpus*, *Elaeocarpus*, *Meliosma*, and *Eurya* ; (ii) the upper hill forests, above 9,000 ft., consisting for the most part of conifers, *Abies Webbiana*, *Picea spinulosa*, *Larix Griffithii*, *Tsuga Brunoniana*, and two junipers, as well as numerous rhododendrons, dwarf willow, and other shrubs ; the bamboo *Arundinaria racemosa* forms a dense growth in places.

(c) The alpine zone, above 12,000 ft., is rich in rhododendrons, which ascend to 16,000 ft. ; the junipers of the upper temperate zone also extend high into this zone.

3. *The trans-Indus region.* This region comprises the trans-Indus hills of the North West Frontier Province and Baluchistan. In the northern part of this region, extending southward as far as the Kurram valley, the forests approximate in type to those of the western portion of the western Himalayan region. Farther south, in Baluchistan, where the rainfall does not exceed 12 in. and is often considerably less, most of the Himalayan conifers disappear, and the forests become much drier and poorer in type ; *Pinus excelsa* is very local in the north of Baluchistan, being confined to places where moisture is held up in the soil, while *P. Gerardiana* forms forests of some extent, as in Zhob and on the Takht-i-Suliman. The chief conifer of Baluchistan is *Juniperus macropoda*, which forms somewhat open forests. Among other trees or shrubs of this region may be mentioned *Pistacia mutica*, *P. Khinjak*, *Fraxinus xanthoxyloides*, *Olea cuspidata*, *Acacia modesta*, *Tamarix* spp., *Crataegus Oxyacantha*, and *Tecoma undulata*. In some parts of the trans-Indus region the small gregarious palm *Nannorhops Ritchieana* occurs in tracts of considerable extent.

4. *The north-western dry region.* This region comprises the plains of the Punjab and Sind, Rajputana, Cutch, and the northern part of Guzerat. The rainfall is less than 30 in., and in most parts of the region is under 20 in., while in the driest parts of Sind less than 5 inches of rain fall in the year. In the extreme north of this region, on the hills and elevated plateaux between the Jhelum and the Indus, the dominant species are *Acacia modesta* and *Olea cuspidata*, with most of the shrubs characteristic of the sub-Himalayan tract to the north. On proceeding south vegetation diminishes towards the desert regions of the southern Punjab, Sind, and Rajputana, and almost disappears in the driest parts. Tree vegetation here exists mainly along the rivers, where the land is subject to periodical inundation. These riverain forests are well exemplified along the Indus in Sind, where there are extensive areas

covered with *Acacia arabica*, *Prosopis spicigera*, *Populus euphratica*, and *Tamarix*; a description of these riverain forests will be found under *Acacia arabica*. The natural forests of the dry plains of the Punjab, Sind, and Rajputana, where they have not been destroyed for cultivation, consist of *Prosopis spicigera*, *Salvadora oleoides*, and *Capparis aphylla*, forming a very open growth. These species rapidly disappear with the extension of irrigation, their place being taken by such trees as *Acacia arabica*, *Albizzia Lebbeck*, *Dalbergia Sissoo*, and others which have escaped from cultivation. To the south-east of this region lie the Aravalli hills and their outliers, commencing with a few isolated rocky hills in the south-east of the Punjab. Here the desert flora of the dry plains gives place to dry and somewhat open types of forest consisting in places almost entirely of *Anogeissus pendula*. Other characteristic species of these hills and the adjacent tracts are *Boswellia serrata*, *Sterculia urens*, *Grewia salvifolia*, *G. pilosa*, *Balanites Roxburghii*, *Acacia Senegal*, *A. leucophloea*, *A. Jacquemonti*, *A. Catechu*, *Dichrostachys cinerea*, *Balsamodendron Mukul*, *Zizyphus nummularia*, and *Euphorbia Nivulia*. These forests are for the most part typical thorn forests.

5. *The Gangetic plain.* The great bulk of the Gangetic plain is a cultivated tract: the forests, where they exist, are of widely different types. The extreme south-west of this region borders on the Aravalli hills, and the forest vegetation is of the type just described. The ravine country south of the Jumna contains open thorn forest of *Acacia arabica*, *A. leucophloea*, and other species. The two most important forest tracts of this region are the sal forests of Oudh and the littoral and tidal forests of the Sundarbans. The Oudh sal forests, as they exist now, are probably mere remnants of the great sub-Himalayan sal belt, which at one time covered a much larger area than it does at present and stretched for some distance into the plains; strictly speaking they can hardly be differentiated from the sub-Himalayan *tarai* forests. These forests are described under *Shorea robusta*. The Sundarbans form an extensive forest tract occupying a flat plain of recent alluvial origin, and still in process of formation, in the southern portion of the Gangetic delta bordering on the Bay of Bengal. The chief species in this tract are *Heritiera Fomes*, *Excaecaria Agallocha*, *Sonneratia apetala*, *S. acida*, *Carapa moluccensis*, *C. obovata*, *Amoora cucullata*, *Aegiceras majus*, *Cynometra ramiflora*, *Avicennia officinalis* and the mangroves *Ceriops Candolleana*, *C. Roxburghiana*, *Kandelia Rheedii*, *Rhizophora mucronata*, and *Bruguiera gymnorhiza*. Further particulars regarding these forests will be found under *Heritiera Fomes* and *Rhizophoraceae*.

6. *The west coast region.* This region, which is one of heavy rainfall, comprises the excessively humid belt of mountainous country running parallel to the west coast of the Indian Peninsula from the south of Guzerat to Cape Comorin, together with the low country between the mountains and the coast. Owing to a gap separating the mountains of Travancore from those to the north of them the flora of this region is carried some distance across the Peninsula at this point. Broadly speaking the forests of this region may be divided into three main types: (a) tropical evergreen or rain forests, (b) mixed deciduous or monsoon forests, and (c) subtropical or temperate evergreen forests of the Nilgiris and other mountains of southern India.

(a) The tropical evergreen or rain forests are characterized by the great luxuriance of their vegetation, which consists of several tiers, the highest containing lofty trees, often with buttressed bases, reaching a height of 150 ft. or more, and the lowest consisting of a dense shrubby evergreen undergrowth. The intermediate tiers consist mainly of evergreen trees crowded together and struggling for light. There is a luxuriant growth of climbers, while the trees are covered with numerous epiphytes. The rain forests of the west coast region are found mainly from North Kanara southwards : much of the forest, however, has been either destroyed by shifting cultivation or cut up by spice and betel-palm gardens, or in the south by rubber plantations. Among the trees of the evergreen forests are *Dipterocarpus indicus*, *Hopea parviflora*, *H. Wightiana*, *Calophyllum tomentosum*, *Cullenia excelsa*, *Dichopsis elliptica*, *Dysoxylum malabaricum*, *Cedrela Toona*, *Vateria indica*, *Canarium strictum*, *Tetrameles nudiflora*, *Mesua ferrea*, *Mangifera indica*, *Sterculia alata*, *Artocarpus hirsuta*, *A. integrifolia*, *A. Lakoocha*, *Acrocarpus fraxinifolius*, *Hydnocarpus Wightiana*, and many Myristicaceae and Lauraceae.

(b) The mixed deciduous or monsoon forests are composed mainly of deciduous trees, which are more or less leafless for a considerable portion of the dry hot season from December to May or June. These forests are rich in woody climbers, but are not so dense as the evergreen forests, nor do they contain such lofty trees. They occur in different parts of this region, but are most plentifully developed in the north. This type of forest, which is essentially a mixed one, is of special importance in that it contains several species of great economic value as timber trees. Among the principal species are *Tectona grandis*, *Dalbergia latifolia*, *Terminalia tomentosa*, *T. paniculata*, *T. belerica*, *Lagerstroemia lanceolata*, *L. parviflora*, *Pterocarpus Marsupium*, *Xylia xylocarpa*, *Adina cordifolia*, *Stephegyne parvifolia*, *Grewia tiliacifolia*, and others : the chief bamboos are *Bambusa arundinacea*, *Dendrocalamus strictus*, and *Oxytenanthera monostigma*, the last named mainly on the upper slopes of the hills. This type of forest merges on the one hand into the evergreen type and on the other into the drier types of mixed deciduous forest in the Deccan region.

(c) The subtropical or temperate evergreen forests, known locally as *sholus*, commence at about 5,000 ft., and are a characteristic feature of the landscape on the Nilgiri, Anaimalai, Palni, and other hill ranges of southern India. At the lower elevations they merge into tropical evergreen, but higher up, at the more temperate elevations, they are composed mainly of evergreen trees of comparatively small size with rounded crowns, and have a rich undergrowth in which species of *Strobilanthes* are well represented. Among the more characteristic trees are *Michelia nilagirica*, *Ternstroemia japonica*, *Eurya japonica*, *Gordonia obtusa*, with species of *Eugenia*, *Ilex*, *Meliosma*, *Euonymus*, *Symplocos*, *Glochidion*, and various Lauraceae. At the lower elevations *Mesua ferrea* is found, and *Hydnocarpus alpina* is common. The two commonest bamboos of these hills are *Arundinaria Wightiana* and *Oxytenanthera Thwaitesii*.

Apart from the three main types just described there are other forest types of a more local character. Among these may be mentioned (i) mangrove forests along tidal creeks ; (ii) littoral forests of *Calophyllum Inophyllum*,

Anacardium occidentale, *Salvadora persica*, *Erythrina indica*, *Ficus tomentosa*, and *Pongamia glabra*; (iii) dwarf forests of a montane type, but containing species characteristic of low elevations, such as *Eugenia Jambolana* and others, at 4,500 ft. on the laterite of the Mahableshwar plateau where the rainfall is over 300 in.; (iv) tree or bush forests of the Nilgiri and other south Indian hills in drier localities than those occupied by the *sholas*, with such species as *Rhododendron arboreum*, *Vaccinium Leschenaultii*, and *Gaultheria fragrantissima*.

Apart from the forest tracts, the upper parts of the Nilgiri and other south Indian hills are characterized by the presence of expanses of open undulating grassland. Exotic trees have been introduced very successfully on these hills, particularly eucalypts and Australian acacias (see under *Eucalyptus* and *Acacia*).

7. *The central Indian region.* This region comprises the country between the Gangetic plain on the north and the Godavari river on the south, and includes the whole of the Central Provinces, Chota Nagpur, Orissa and the Circars, Khandesh, the southern part of Guzerat, and the greater part of the Central India States. Within this region fall the two great hill ranges of central India, the Vindhya and Satpura hills. The rainfall varies from 25 to 65 inches, except that the latter is exceeded on the plateaux of Pachmarhi and Chikalda. The great bulk of the forests in this region consist either of (a) mixed deciduous forests of a type which is virtually a dry form of monsoon forest, or (b) sal forests, or (c) thorn forests. The distribution of these types is determined partly by climatic conditions, but also to a considerable extent by soil conditions.

(a) The mixed deciduous forests vary in composition, but the prevailing trees are *Tectona grandis*, *Terminalia tomentosa*, *T. belerica*, *T. Chebula*, *Anogeissus latifolia*, *Lagerstroemia parviflora*, *Pterocarpus Marsupium*, *Dalbergia latifolia*, *Ougeinia dalbergioides*, *Cassia Fistula*, *Acacia Catechu*, *Butea frondosa*, *Adina cordifolia*, *Stephegyne diversifolia*, *Bridelia retusa*, *Phyllanthus Emblica*, *Cleistanthus collinus*, *Diospyros Melanoxyton*, *Bassia latifolia*, *Snymidia febrifuga*, *Schrebera swietenoides*, *Chloroxylon Swietenia*, *Odina Wodier*, *Buchanania latifolia*, *Schleichera trijuga*, and various other trees; the prevailing bamboo is *Dendrocalamus strictus*. On ridges and in other dry situations the forest is often of a special kind in which *Boswellia serrata*, *Sterculia urens*, and *Cochlospermum Gossypium* are the chief species. In the moister types of forest to the south-east of this region *Xylia xylocarpa* becomes common. As a general rule the mixed deciduous forests of this region do not contain trees of large dimensions, and compare unfavourably in this respect with the mixed deciduous forests of the west coast or of Burma. In the more favourable localities, as in moist ravines and on deep fertile soil, forest of very fair quality is produced, but over a considerable portion of the region the forest is of a dry type often merging into thorn forest. Teak trees of small size are very plentiful in places. There are various special types of mixed deciduous forest in this region, one of the most notable being the *anjan* (*Hardwickia binata*) type found either on trap or on sandy and gravelly soil overlying granite, schist, quartzite, conglomerate, or sandstone (see under *Hardwickia binata*). In parts of Central India *Anogeissus pendula* grows gregariously, forming a special type of forest. Some of the drier and more open types of mixed

deciduous forest, in which rather stunted trees are scattered over grassy expanses, may be classed as dry savannah forests.

(b) The sal forests extend through the eastern part of the Central Provinces, the greater part of Chota Nagpur and Orissa, and the north-eastern portion of the Madras Presidency. Their distribution is determined largely by the hygroscopicity of the soil and subsoil, for which reason they avoid trap areas, which are too dry for their existence. These forests are described in some detail under *Shorea robusta*. Associated with the sal forests are occasional tracts of savannah land.

(c) Thorn forests occur in all the drier parts of this region, chiefly on the more level ground on the extensive plateaux of Central India. They are of an open character, vary in composition, and consist to a large extent, though by no means exclusively, of thorny species, many of which belong to the Leguminosae; among characteristic species of the thorn forests of this region may be mentioned *Acacia arabica*, *A. leucophloea*, *A. Catechu*, *Dichrostachys cinerea*, *Balanites Roxburghii*, *Butea frondosa*, *Phyllanthus Emblica*, *Zizyphus Xylopyrus*, *Z. nummularia*, and *Z. Oenoplia*. *Prosopis spicigera* occurs only in the driest parts of this region. Thorn forest is specially characteristic of trap areas and black cotton soil, though by no means confined to such ground.

8. *The Deccan and Carnatic.* This region includes the whole of peninsular India south of the Godavari river with the exception of that portion which falls into the humid west coast region. It is divisible into two main sub-regions: (a) the elevated and often hilly plateau of the Peninsula, which may be termed the Deccan sub-region, and (b) the low land along the east (Coromandel) coast, which may be termed the Carnatic sub-region. Throughout the greater part of the former the rainfall is less than 40 in., this amount being exceeded only at certain elevated points which intercept the monsoon currents (e.g. Yercaud 63 in.). The latter sub-region receives the full benefit of the north-east monsoon, and has a rainfall which throughout the greater part of its extent varies from 40 to nearly 60 in.

(a) The Deccan sub-region is characterized by dry open types of forest, varying from mixed deciduous forest similar to the drier types found in the central Indian region, to open thorn forest similar to that of the driest parts of that region, with *Prosopis spicigera* more plentiful towards the south. Other typical thorn-forest species, which do not occur in other Indian regions, are *Acacia planifrons* and *A. Latronum*, while *Albizzia amara* scarcely extends beyond this region. In these thorn forests *Cassia auriculata* is a conspicuous gregarious shrub. In the more barren rocky tracts a semi-desert flora appears, with fleshy Euphorbiaceae, *Capparis divaricata*, *C. aphylla*, and other xerophytic plants. Among many special types of forest in this sub-region the following may be mentioned: (i) *Hardwickia binata* tracts occur in various localities, mainly from Salem and North Arcot to the Godavari river, usually on gravelly sand or red sandy loam, either in gregarious patches or in mixture with *Anogeissus latifolia*, *Soymida febrifuga*, *Terminalia tomentosa*, and other trees. (ii) *Pterocarpus santalinus* tracts occupy a limited range mainly in the hills of Cuddapah and North Arcot, extending into Kurnool and Nellore, with an outlier in the hills of Chingleput; this tree occurs in a dry type of mixed forest on well-drained rocky ground or stony and gravelly soil, among its more

typical associates being *Pterocarpus Marsupium*, *Hardwickia binata*, *Dalbergia latifolia*, *Acacia leucophloea*, *Albizzia odoratissima*, *Chloroxylon Swietenia*, *Terminalia Chebula*, and *Anogeissus latifolia*. (iii) The most important sandalwood (*Santalum album*) areas are found in the uplands of Mysore, Coorg, and parts of Madras, chiefly in Coimbatore, Salem, the Nilgiris, and North Arcot. The sandalwood grows in open scrub forests on well-drained stony or gravelly soil or red ferruginous loam (see under *Santalum album*). (iv) *Shorea* forests of this sub-region are represented by two separate species, *S. Tumbuggaia* and *S. Talura*, each with a limited distribution; the former occurs in comparatively dry situations and somewhat resembles the sal in habit, while *S. Talura* is found more in damp ravines, and extends into the west coast region. (v) A special type of thorn forest is found in the extreme south of the Peninsula in the Madura and Tinnevely districts, where the country is sheltered from the monsoon by the Palni hills and the hills of Ceylon, and is very hot and arid: here is found an open xerophilous woodland consisting largely of *Acacia planifrons*, with its spreading umbrella-shaped crown, and thickets of the thorny *A. Latronum*.

(b) The Carnatic sub-region contains, besides a certain extent of forest of the Deccan type, another type which may be termed dry evergreen, in which the chief species include *Mimusops hexandra*, *M. Elengi*, *Diospyros Ebenum*, *Strychnos Nux-vomica*, *Eugenia* spp., *Pterospermum suberifolium*, *P. Heyneanum*, *Memecylon edule*, and *Chloroxylon Swietenia*. Although the trees are not of large dimensions the forests where carefully preserved are dense, but many of them through over-felling have been reduced to the condition of thorny thickets of *Randia*, *Canthium*, *Dichrostachys*, *Flacourtia*, and *Zizyphus*. Mangrove forests occur at the mouths of the rivers, while on the sand near the sea the palm *Phoenix farinifera* and the grass *Spinifex squarrosus* form dense thickets. Successful casuarina plantations have been formed along the coast on sandy soil.

9. *Assam*. The Assam region outside the sub-Himalayan tract, which forms part of the eastern Himalayan region, comprises the Brahmaputra and Surma valleys together with the intervening hill ranges (the Garo, Khasi, and Jaintia hills) and the Naga, Manipur, and Lushai hills on the eastern and south-eastern frontiers of Assam. Over the greater part of this region the rainfall exceeds 80 in., while Cherrapunji in the Khasi hills, with a normal rainfall of 460 in., is one of the rainiest spots in the world. In part of the Nowgong district the rainfall is as low as 45 in., but this is exceptionally dry for this region. The vegetation, as might be expected, is luxuriant. The valleys, where not under tea or agricultural crops, are clothed with expanses of tall savannah grass or with dense forest often of an evergreen type. Among the more characteristic species of the valleys and lower hills are *Mesua ferrea*, *Artocarpus Chaplasha*, *Michelia Champaca*, *Lagerstroemia Flos-Reginae*, *Amoora Wallichii*, *Vatica lanceaefolia*, *Alstonia scholaris*, *Cinnamomum Cecidodaphne*, *Dillenia indica*, *Dysoxylum binectariferum*, *Garcinia* spp., *Eugenia* spp., *Carallia lucida*, *Baccaurea sapida*, *Aquilaria Agallocha*, *Sterculia alata*, *Cedrela Toona*, *Gmelina arborea*, *Morus laevigata*, *Stereospermum chelonoides*, *Ficus elastica* and many other species of *Ficus*, *Terminalia citrina*, *T. myriocarpa*, and many other trees. There are various bamboos, of which

perhaps the commonest is *Dendrocalamus Hamiltonii*, and there is often a dense impenetrable undergrowth of canes, climbers, and evergreen shrubs. Among the more typical trees in riverain areas are *Albizzia procera*, *Bischoffia javanica*, *Bombax malabaricum*, *Anthocephalus Cadamba*, *Elaeocarpus assamicus*, and *Lagerstroemia Flos-Reginae*. South of the Brahmaputra sal forest occurs in the Garo hills and in the Kamrup district.

The hill forests of the Assam region approximate in type to those of the eastern Himalayan region, except that there is no alpine zone. These hill forests may be separated broadly into evergreen broad-leaved forests and pine forests. The former include species of *Magnolia*, *Manglietia*, *Michelia*, *Acer*, *Prunus*, *Pyrus*, *Pieris ovalifolia*, *Rhododendron arboreum*, *Bucklandia populnea*, *Alnus nepalensis*, *Betula alnoides*, *Carpinus viminea*, and many species of *Quercus*. The pine forests occur at elevations of 2,500 ft. and over, particularly at 4,000–4,500 ft., and are composed of the one species *Pinus Khasya*. Shifting cultivation has destroyed much of the natural forest growth on these hills. The hill-tops of the Assam region, like those of the Nilgiris, are open grasslands with trees and shrubs identical with or closely related to those of the Nilgiris. The mountains to the east are often covered with bamboos.

10. *Chittagong and Arakan*. This is another region of heavy rainfall, the lowest normal rainfall recorded being 96 in., at Chittagong, while in places on the Arakan coast the normal rainfall exceeds 200 in. Along the coast, particularly of Arakan, there are extensive mangrove swamps, while strips of *Casuarina equisetifolia* occur here and there on beaches of pure sand. The inland forests are of evergreen or moist mixed deciduous types, and resemble those of the moister parts of Burma. Among the more characteristic trees of the evergreen forests are *Mesua ferrea*, *Dipterocarpus* spp., *Vatica* spp., *Hopea odorata*, *Sterculia alata*, *Dysoxylum binectariferum*, *Chickcrassia tabularis*, *Cedrela Toona*, *Acrocarpus fraxinifolius*, *Swintonia floribunda*, *Buchanania lancifolia*, *Carallia lucida*, *Eugenia* spp., *Machilus* spp., *Baccaurea sapida*, *Tetrameles nudiflora*, and *Artocarpus Chaplasha*. Palms, including canes, are numerous. In the hill tracts various species of *Quercus* and *Castanopsis* are found.

The mixed deciduous forests contain *Dillenia pentagyna*, *Miliusa velutina*, *Pterospermum semisagittatum*, *Erythrina stricta*, *Xylia dolabriformis* (Arakan), *Albizzia stipulata*, *Bombax malabaricum*, *Terminalia tomentosa*, *T. belerica*, *T. Chebula*, *Anogeissus acuminata*, *Lagerstroemia Flos-Reginae*, *Duabanga sonneratioides*, *Adina cordifolia*, *Stephegyne parvifolia*, *S. diversifolia*, *Homalium tomentosum*, *Vitex peduncularis*, *V. glabrata*, and many other species.

Of several species of bamboo by far the most important is the single-stemmed *Melocanna bambusoides*, which covers immense tracts in the hills of Chittagong and Arakan; its growth is encouraged by shifting cultivation, which destroys the tree-growth and leaves the bamboo in sole possession of the ground.

11. *Burma*. The Burmese region, which is here taken to mean the whole of Burma including the Shan States but excluding Arakan, may be divided roughly into three zones of rainfall corresponding approximately to three dominant forest types or climatic forest formations; these zones are A. the humid zone, B. the medial zone, C. the dry zone. A. The humid zone,

with a rainfall of 120 in. or more, comprises Tenasserim and Martaban with the country east of the Sittang river up to about 19° N. lat. and perhaps in part also the Salween drainage farther north; also probably the far north of Upper Burma. If Arakan were included with Burma it would fall into this zone. The forests are mainly of the tropical evergreen type, but deciduous forests also occur to some extent, particularly where the rainfall is less than 150 in. B. The medial zone, with a rainfall of 40 to 120 in., comprises the greater part of Pegu and of Upper Burma outside the dry zone on the one hand and the humid tracts of the far north on the other. The dominant type of forest is the mixed deciduous type, otherwise termed monsoon forest, though tropical evergreen forests, sometimes of considerable extent, are also met with in moist situations, and other evergreen types are met with in the hills. The deciduous forests of this zone are, economically speaking, the most important in the province, in that they are the home of the teak and many other valuable timber trees. C. The dry zone, with a rainfall of less than 40 in., comprises the dry tract occupying the centre of the southern part of Upper Burma and extending into the Thayetmyo district of Lower Burma. In the driest parts of this zone the normal rainfall is only slightly over 20 in. The dominant type of forest is open thorn scrub.

Kurz, in his *Preliminary Report on the Forest and other Vegetation of Pegu*, 1875, and in the introduction to his *Forest Flora of British Burma*, 1877, has described in some detail the forests of what is now known as Lower Burma, and most of the types recognized by him apply to the whole province as now constituted. In his *Preliminary Report* he classified the forests of British Burma, as it then was, into seven main types and a number of sub-types. In his *Forest Flora* he reclassified them into eight main types, namely, A. Evergreen forests—I littoral, II swamp, III tropical, IV hill forests; B. Deciduous forests—V open, VI dry, VII mixed, VIII dune forests.

A classification of the forests of Burma is by no means easy, for although there is little difficulty in recognizing several well-marked types these often tend to merge into each other, and the border line is not always easy to determine. The following classification may be adopted here for brief descriptive purposes: (a) Tidal forests, (b) beach and dune forests, (c) swamp forests, (d) tropical evergreen or rain forests, (e) dry evergreen forests, (f) subtropical or temperate evergreen forests, (g) mixed deciduous forests, (h) deciduous dipterocarp forests, (j) thorn forests. There are various types of savannah forest, but they may be included in one or other of these main classes, into which they usually merge.

(a) Tidal forests comprise (i) mangrove forests on low alluvial flats within tidal limits at the mouths of the rivers, which contain true mangroves of the genera *Rhizophora*, *Ceriops*, *Kandelia*, and *Bruguiera*, together with species of other genera characteristic of this formation, such as *Carapa*, *Lumnitzera*, *Sonneratia*, *Aegiceras*, and *Avicennia*, together with the gregarious palm *Nipa fruticans* (see under Rhizophoraceae); (ii) forests farther inland on ground inundated only by spring tides, containing such species as *Heritiera Fomes*, *Pongamia glabra*, *Erythrina* spp., *Excaecaria Agallocha*, *Thespesia populnea*, some of the species of the mangrove forests, and the palm *Phoenix*

paludosa; these are the forests to which the term 'tidal forest' is usually applied.

(b) Beach and dune forests form comparatively narrow belts and strips along the coast of Tenasserim on the calcareous sand of beaches elevated above high-tide limits and on sand-dunes formed by the action of the wind. The trees are partly evergreen and partly deciduous, and include *Casuarina equisetifolia* (on sand-dunes), *Pongamia glabra*, *Erythrina indica*, *Thespesia populnea*, *Hibiscus tiliaceus*, *Calophyllum Inophyllum*, *Odina Wodier*, *Pandanus odoratissimus*, and others.

(c) Swamp forests are characteristic of inland fresh-water swamps on low-lying alluvial ground usually near rivers and lakes, and are subject to inundation during the rainy season. The species, the majority of which are evergreen, include *Barringtonia acutangula*, *Xanthophyllum glaucum*, *Anogeissus acuminata*, *Mangifera* spp., *Elaeocarpus hygrophilus*, *Eugenia operculata*, *Ixora parviflora*, *I. nigricans*, *Symplocos leucantha*, *Garcinia succifolia*, and others, and there is often a dense undergrowth of *Combretum trifoliatum* and *tetragonocarpum*, *Capparis tenera*, *Derris elegans*, and other shrubs and climbers; the higher ground is sometimes covered with tracts of coarse savannah grass.

(d) Tropical evergreen or rain forests are developed most extensively in Tenasserim and Martaban, where the rainfall for the most part exceeds 150 in.; they occur also to a considerable extent in the humid tracts in the far north of Upper Burma, particularly north of Mogaung. Elsewhere throughout the province outside the dry zone they occur to a greater or less extent in moist localities, particularly in shady valleys where there is a perennial water-supply. These forests are similar in type to the evergreen forests of western India and of the eastern sub-Himalayan tract. They are very rich in species, and comprise several tiers of vegetation, of which the uppermost consists of lofty and often deciduous trees, many of which have plank buttresses; the lower tiers consist mainly, if not entirely, of evergreen species struggling together in great profusion, while there is often a dense undergrowth of shade-bearing palms; climbers, including several kinds of cane, are numerous, and sometimes form an impenetrable tangled mass. Where the cover is not too dense there is often a rich undergrowth of herbaceous plants or evergreen shrubs, and frequently a soil-covering of ferns, but the overhead cover is sometimes so heavy that nothing will grow in the deep shade beneath it. Several species of bamboo are found in these forests, but in Lower Burma perhaps the commonest is *Teinostachyum Helferi*, a straggling evergreen bamboo which forms impenetrable thickets in moist localities: in Upper Burma *Dendrocalamus Hamiltonii* is common. Among the lofty trees of the upper tier in these forests are *Dipterocarpus alatus*, *D. turbinatus*, *Hopea odorata*, *Parashorea stellata*, *Sterculia alata*, *Tetrameles nudiflora*, *Acrocarpus fraxinifolius*, *Pentace burmanica*, *Swintonia floribunda*, and *Antiaris toxicaria*, while among other trees characteristic of these forests are *Artocarpus Chaplasha*, *Albizzia lucida*, *Mangifera indica*, *Baccaurea sapida*, *Amoora Rohituka*, and species of *Elaeocarpus*, *Holigarna*, *Pterospermum*, *Garcinia*, *Diospyros*, *Eugenia*, *Macaranga*, *Ficus*, *Myristica*, and many Lauraceae. There is little difference in character between the evergreen forests of Tenasserim and those of the north of Upper Burma. In the latter region most of the species just mentioned occur,

with the addition of *Ficus elastica* in certain localities, notably the Hukong valley.

(e) Dry evergreen forests form a distinct xerophytic type which, so far as is known, is developed only to a limited extent. This type is exemplified by the vegetation which occurs on limestone rocks in parts of the Ruby Mines district, and which consists of thorny evergreen species and euphorbias.

(f) The subtropical and temperate evergreen forests of the hill regions of Burma, which begin at about 3,000 to 3,500 ft., closely resemble those of Assam in the character of their forest vegetation, which is essentially evergreen. They are roughly divisible into moist and dry broad-leaved forests and pine forests. The moist evergreen forests, which occur mainly from 3,000 to 6,000 ft., are of a subtropical or warm temperate character, and are typical rain forests; they are damp, with lofty trees and luxuriant vegetation, resembling the tropical evergreen forests except that the prevailing species are different. The most characteristic trees of these forests are various species of *Quercus*, *Castanopsis*, *Eugenia*, and *Ficus*, some Magnoliaceae, many Lauraceae, *Ilex*, *Ternstroemia japonica*, *Bucklandia populnea*, *Ostodes paniculata*, and others. There is often a dense undergrowth of shrubs, climbers, and herbaceous plants, and the ground is sometimes covered with *Strobilanthes*. Grass is rarely found as a soil-covering.

In the drier hill forests the trees are not so tall as those of the damp hill forests, and at the higher elevations they become stunted, with low rounded crowns and short boles, forming the type known as elfin-wood. The vegetation of the drier hill forests is less luxuriant than that of the moist forests, and the climbers are neither so numerous nor so large. There is an undergrowth of shrubs and often of bracken fern (*Pteris aquilina*), or a soil-covering of grass where the crop is open. These forests are composed of various species of *Quercus* and *Castanopsis*, with *Eurya*, *Schima Wallichii* and *S. Noronhae*, *Ternstroemia japonica*, *Bucklandia populnea*, *Alnus nepalensis*, several Lauraceae and many Ericaceae, including species of *Agapetes* and *Vaccinium*, *Rhododendron arboreum* and other species, *Gaultheria fragrantissima*, and *Pieris ovalifolia*.

The pine forests (*Pinus Khasya*) are found for the most part at elevations of over 4,000 ft., mainly in the region of the drier evergreen forests; the pine forms pure crops of considerable extent, but is also found scattered in broad-leaved forests. A more detailed description is given under *Pinus Khasya*. The other Burmese pine, *P. Merkusii*, belongs properly not to the region of the evergreen forests but to that of the deciduous dipterocarp forests at lower elevations than *Pinus Khasya*.

(g) The mixed deciduous forests are, economically speaking, the most important forests of Burma, in that they are the home of the teak and many other valuable timber trees. They are found for the most part in places where the rainfall varies from 40 to 120 in., but they extend into regions of heavier rainfall, while in regions of less than 40 in. they exist as dry forms merging into thorn forest. The mixed deciduous forests, other than the drier forms, are typical monsoon forests. Most of the trees are leafless for a considerable part of the hot season and do not put on their new foliage till well on in that season or even till the beginning of the rainy season. Many distinct

forms of mixed deciduous forest may be distinguished, but for our purpose it will be sufficient to distinguish three main forms: (i) upper mixed forests, (ii) lower mixed forests, and (iii) dry mixed forests. The terms upper and lower mixed forests are those employed by Kurz in his description of the forest vegetation of Pegu, and are well understood locally: a somewhat more detailed description of them than is given here will be found under *Tectona grandis*.

(i) Upper mixed forests are situated on well-drained hilly or undulating ground, and are usually characterized by the presence of bamboos in quantity. Two main sub-types are distinguishable, namely moist and dry mixed forest, these being determined largely by the species of bamboo present. In the Pegu Yoma the typical bamboo of the moist forests is *Bambusa polymorpha*, with *Cephalostachyum pergracile* in its more luxuriant form: in the more northerly parts of Upper Burma *B. polymorpha* is replaced by *Dendrocalamus Brandisii*, *D. Hamiltonii*, *D. membranaceus*, and other bamboos. The prevailing bamboo of the dry mixed forests is *Dendrocalamus strictus*, but *Cephalostachyum pergracile* in somewhat stunted form extends into fairly dry forest; *Thyrsostachys Oliveri* in Upper Burma is somewhat similar in habit to *Cephalostachyum*, though if anything it frequents rather drier forest. *Bambusa Tulda* extends into dry as well as moist forest. Many of the tree species are common to both dry and moist forest, though as a general rule their growth is superior in the latter. Among these species are *Tectona grandis*, *Xylia dolabriformis*, *Terminalia tomentosa*, *T. belerica*, *Homalium tomentosum*, *Adina cordifolia*, *A. sessilifolia*, *Stephegyne diversifolia*, *Bombax insigne*, *Gmelina arborea*, *Berrya Ammonilla*, *Vitex glabrata*, *Odina Wodier*, *Anogeissus acuminata*, and *Spondias mangifera*. More characteristic of the moister forests are *Dipterocarpus alatus*, *Lagerstroemia Flos-Reginae*, and *L. tomentosa*, while in the drier types *Acacia Catechu*, *Pterocarpus macrocarpus*, *Terminalia Chebula*, *Pentacme suavis*, and other species make their appearance. A special form of dry forest, containing few or no bamboos, is that known in the Pegu Yoma as *thitkyin*, in which the characteristic trees are teak, *Xylia*, *Terminalia tomentosa*, *Homalium tomentosum*, and *Lagerstroemia Flos-Reginae*, with an undergrowth often consisting of thorny twiners: there is sometimes a dense advance growth of *Xylia*.

(ii) Lower mixed forests occur on flat alluvial ground, and are characterized generally by the scarcity or absence of bamboos. Teak occurs in well-drained areas, and is sometimes very plentiful, attaining large dimensions. *Xylia dolabriformis* likewise occurs only on well-drained areas. Lower mixed forests vary greatly in character and composition. Among the commoner trees of the more typical lower mixed forests, besides the two mentioned, are *Lagerstroemia Flos-Reginae*, *L. tomentosa*, *Dipterocarpus alatus*, *Terminalia tomentosa*, *T. belerica*, *T. Chebula*, *Adina cordifolia*, *A. sessilifolia*, *Stephegyne diversifolia*, *Odina Wodier*, *Careya arborea*, *Dillenia pentagyna*, *Dalbergia cultrata*, *D. purpurea*, and *Anogeissus acuminata*. Where these forests become open owing to excessive felling, severe fires, or inundation, they become savannah forests, in which the trees are scattered in an expanse of coarse grass; in these savannah forests, among the more typical trees in moist tracts are *Butea frondosa* and *Albizzia procera*. The lower mixed forests merge in places into tropical ever-

green on the one hand or into *indaing* (deciduous dipterocarp forest) on the other, there being varying transition stages. There are also special types of lower mixed forest where certain trees become gregarious, for instance *Terminalia tomentosa* var. *macrocarpa* on clayey ground, forming open savannah forest resembling *indaing*, with a soil-covering of grass; stunted *Dalbergia cultrata* and *D. purpurea* may also form a special type on stiff clayey ground. Another form of savannah forest on stiff alluvial soil is that composed largely of species of *Gardenia* and *Randia*. These savannah types ought strictly speaking to be classified separately, but they merge so frequently into lower mixed forest that they can be conveniently dealt with along with it in a brief description like the present one.

(iii) Dry mixed forests, which are found for the most part where the rainfall is between 35 and 60 in., represent various transition forms between the usual mixed deciduous or monsoon forest on the one hand and thorn forest or deciduous dipterocarp forest on the other. They are found typically on the fringes of the dry zone, although they enter that zone, and also occur some distance outside it. The character and composition of the forest varies considerably. Many of the trees of the upper and lower mixed deciduous forests are found in these dry types, but they are stunted, while certain typical trees of the dry zone occur in addition. The crop is usually of an open nature, and merges into dry savannah forest. These dry types of forest are not wholly climatic; they may be due to dry hard or shallow soil. The typical bamboo is *Dendrocalamus strictus*, and among the commoner trees are *Terminalia tomentosa*, *T. Oliveri*, *Tectona Hamiltoniana*, *Pentacme suavis*, *Shorea obtusa*, *Phyllanthus Emblica*, *Acacia Catechu*, *Pterocarpus macrocarpus*, *Millettia* spp., *Dalbergia Oliveri* (local), *D. cultrata*, *Cassia renigera*, *Bauhinia variegata*, *B. racemosa*, *Diospyros burmanica*, and sometimes stunted teak and *Xylia dolabriformis*.

(h) The deciduous dipterocarp forests of Burma, locally known as *indaing*, are a characteristic feature of the forest vegetation of the province, and cover large areas. They are found most commonly on laterite, but occur also on sandy and gravelly soil or on gravelly clay. In the normal type of *indaing* the dominant species is *Dipterocarpus tuberculatus*, which grows gregariously, and with it are associated *Pentacme suavis*, *Shorea obtusa*, *Melanorrhoea usitata*, *Buchanania latifolia*, *Diospyros burmanica*, and other trees characteristic of this type of forest. The forest is usually of a somewhat open type, and there is frequently a soil-covering of grass, with shrubs such as *Indigofera*, *Flemingia*, *Desmodium*, and others, or stretches of the dwarf palm *Phoenix acaulis*. Open *indaing* forest is of the true savannah type. A form of *indaing* in which *Dipterocarpus tuberculatus* is absent is that which occurs frequently on ridges and in other dry localities; here the dominant species is *ingyin* (*Pentacme suavis*), which is frequently associated with *Shorea obtusa* and other trees characteristic of *indaing*. These *ingyin* forests extend to the dry zone of Upper Burma, where the rainfall is less than 40 in. In the hills *Dipterocarpus tuberculatus* is often replaced by *D. obtusifolius*, and *Pinus Merkusii* becomes a constituent species of some of the dipterocarp forests of the hills of Martaban and Tenasserim, while farther north *P. Khasya* enters these forests at their upper limits. A more detailed account of these deciduous dipterocarp forests

will be found under *Dipterocarpus tuberculatus*, *D. obtusifolius*, and *Pentacme suavis*.

(j) The thorn forests of Burma are practically confined to the dry zone, where the rainfall varies from 23 to 40 in. In general appearance these forests resemble the thorn forests of the Indian Peninsula; they are of an open character and consist largely of thorny species, together with some characteristic unarmed trees, while on dry shallow soils they are reduced to the condition of open scrub. Among the commoner species of trees and shrubs are *Acacia Catechu*, *A. leucophloea*, *Dichrostachys cinerea*, *Tectona Hamiltoniana*, *Terminalia Oliveri*, *Capparis burmanica*, *Phyllanthus Emblica*, *Zizyphus Jujuba*, *Flacourtia Cataphracta*, *Carissa spinarum*, *Gardenia turgida*, *G. sessiliflora*, and *Limonia acidissima*.

12. *The Andamans.* The forests of the Andamans resemble those of Burma in general features; they differ to some extent in individual species, though many species are identical. The climate of the Andamans is warm and equable. The rainfall at Port Blair is 118 in., but judging by the aspect of the forests it is probably somewhat less in the North Andaman. The main types of forest in the Andamans are (a) mangrove forests, (b) beach forests, (c) evergreen forests, (d) semi-evergreen and deciduous forests, and (e) diluvial forests.

(a) The mangrove forests are of the usual type of mangrove swamp on muddy flats between high and low tide limits at the mouths of creeks and in sheltered backwaters. The outer limits of the mangrove swamp, nearest the sea, are composed mainly of *Rhizophora mucronata* and *R. conjugata*, while farther from the sea these species gradually give place to *Ceriops Candolleana*, *Kandelia Rheedii*, *Bruguiera gymnorhiza*, *B. parviflora*, *Carapa obovata*, *C. moluccensis*, *Cynometra ramiflora*, *Lumnitzera racemosa*, *Sonneratia acida*, and other species. On the banks of creeks or in places farthest from the sea and only reached by the highest tides are found *Heritiera littoralis* and *Aegiceras majus*.

(b) Beach forests take the form of comparatively narrow strips along raised beaches of sand, shells, and coral above high-tide limits. Among the commoner trees and shrubs of this type of forest are *Mimusops littoralis*, which sometimes forms pure belts, *Calophyllum Inophyllum*, *Terminalia Cutappa*, *Erythrina indica*, *Pongamia glabra*, *Heritiera littoralis*, *Thespesia populnea*, *Azizelia bijuga*, *Hibiscus tiliaceus*, *Odina Wodier*, *Pandanus* sp., and *Ximenia americana*.

(c) Evergreen forests are confined for the most part to the ridges and upper slopes of the hills. In the South and Middle Andamans their distribution is further determined by the presence of micaceous sandstone, which favours the growth of this type of forest. The most characteristic trees of the evergreen forests are several species of *Dipterocarpus*, including *D. turbinatus*, *D. alatus*, *D. incanus*, and others, *Hopea odorata*, *Planchonia andamanica*, *Artocarpus Chaplasha*, *A. Lakoocha*, *Mesua ferrea*, *Myristica Irya*, *Calophyllum spectabile*, *Albizia Lebbek*, *Diospyros Kurzii*, and *Podocarpus neriifolia*. There is a dense undergrowth of canes and other climbers, including the climbing bamboo *Dinochloa andamanica*.

(d) Semi-evergreen and deciduous forests occupy as a rule the lower slopes and undulating ground between the mangrove or beach forests and the

evergreen forests, but in the South and Middle Andamans their distribution is also determined by the geological formation, since they are found almost entirely on metamorphosed and indurated clay and shale, conglomerate, quartzite, limestone, and hard coarse-grained sandstone. On hot southerly slopes these forests become typically deciduous, but elsewhere they are commonly of a semi-evergreen character. The most important timber tree of these forests is the padauk (*Pterocarpus dalbergioides*), and with it are found *Lagerstroemia hypoleuca*, *Terminalia bialata*, *T. Mannii*, *Albizzia Lebbek*, *Bombax insigne*, *Odina Wodier*, *Sterculia* spp., *Careya arborea*, and *Adenanthera pavonina*, as well as many of the trees of the evergreen forests. The undergrowth consists mainly of shade-bearing shrubs and small trees, with some palms and canes, but it is not so dense and impenetrable as in the evergreen forests.

(e) The diluvial forests occur on diluvial deposits of deep sandy soil lying between the mangrove forests and the hills. They contain trees of both the evergreen and semi-evergreen types, including *Dipterocarpus* spp., *Lagerstroemia hypoleuca*, *Bombax insigne*, *Terminalia bialata*, *T. Catappa*, *Sterculia alata*, and *Pterocarpus dalbergioides*. There is a dense impenetrable undergrowth of climbing bamboo, canes, and creepers, but as the mangrove swamps are approached the bamboos and canes disappear and the undergrowth consists largely of palms such as *Phoenix paludosa*, *Licuala*, and *Areca triandra*, while littoral species of trees such as *Heritiera littoralis* and *Cynometra ramiflora* make their appearance.

OECOLOGICAL FACTORS AND CLASSIFICATION IN RELATION TO INDIAN FORESTS. The foregoing brief account of the forest vegetation of India is sufficient to indicate that the various types of forest may be due primarily either to climatic or to edaphic factors, the latter term denoting factors connected with the soil as apart from the climate. It is now generally accepted by plant-geographers that the differentiation in the earth's vegetation is controlled by three main factors, temperature, atmospheric precipitation (including winds, which are desiccating agents), and soil: temperature and climatic humidity determine the flora and the vegetation, while changes of soil produce changes in the plant communities from place to place over areas of greater or less extent where the climate remains unchanged. Climatic and edaphic factors, however, cannot be considered separately in examining plant communities, which are the result of a combination of both. Climate is responsible for wide differences in the forest vegetation, such for instance as exist between the semi-desert flora of the north-western dry region and the tropical evergreen forest flora of the west coast of India, or between the latter and the temperate evergreen forest of high altitudes; the dominating factor in the former case is rainfall and in the latter temperature. Climate, however, is not responsible for the marked differences in plant communities which are so frequently observed in adjacent regions where the climatic conditions are identical. Take for instance the sharp line of division between the sal and teak forests of the Indian Peninsula, or the occurrence in Burma of that distinctive type of dipterocarp forest known as *indaing*, which is found over areas of greater or less extent alternating with mixed deciduous or evergreen forest, or the prevalence of mangrove forests on mud flats within tidal limits. In these

three instances edaphic factors predominate in determining the character of the plant communities.

The various forest types of India can generally be referred to one or other of the woodland formations recognized by oecologists and plant-geographers, whose classifications have been based for the most part on the amount of water available for growth. For our present purpose we may follow Schimper's¹ broad classification of formations into two main oecological groups—(i) climatic or district formations and (ii) edaphic or local formations; these we may proceed to consider in turn in so far as they relate to India.

(i) *Climatic formations.* The three main types of climatic formation—woodland, grassland, and desert—are admirably represented in India. There the constant struggle for supremacy between woodland and grassland, in which conditions produced by the destructive action of man tend to favour the latter against the former, is strongly in evidence. Thus the clearing of forest in many cases results in the usurpation of the ground by grass; fire and grazing frequently have the same effect, and when these are combined with the clearing of forest by man the effect is the more marked. Where desert conditions are approached the types of woodland and grassland are stunted, and the struggle between them ceases, the struggle of both being against adverse climatic conditions. Deserts are oecologically speaking open formations, whereas woodland and grassland are closed formations; in the two latter there is a constant struggle for space, whereas in deserts there is much unoccupied space, a large proportion of the seed failing to germinate and numbers of seedlings perishing.

It is not easy to determine within definite limits the climate necessary to produce different types of woodland. Schimper notes that the higher the temperature the greater the rainfall necessary to produce hygrophilous trees: in the tropics these require a rainfall of at least 150 cm. (about 60 in.), whereas in cool regions of the temperate zone a rainfall of 60 cm. (about 24 in.) is sufficient. Soil factors, however, greatly modify any general statement of this kind, and the presence of water in the soil would mitigate to a large extent the effect of a small rainfall. In the dry plains of the Punjab irrigation has converted the natural semi-desert scrub into forest of a tropophilous type. Brandis says that in India really successful forests occur only where the rainfall is 40 inches and over, and that a luxuriant vegetation is limited to localities where the rainfall is much greater. Deserts, as Schimper notes, occur where the rainfall is never over 300 mm. (about 12 in.) and is usually much less: this definition of a desert climate applies to Sind, Baluchistan, the south-west Punjab, the southern part of the North West Frontier Province, and western Rajputana. Deserts are found for the most part outside the tropical lines: they are characterized by summer temperatures which are among the highest in the world, as well as by great atmospheric dryness, which acts in the same way as heat.

The chief climatic woodland formations in India are either tropical or temperate, the latter owing their existence primarily to elevation. In India Schimper's tropical woodland climatic formations, rain forest, monsoon forest, savannah forest, and thorn forest, are well exemplified: their main characters are as follows:

¹ A. F. Schimper, *Plant Geography upon a Physiological Basis*, Eng. ed., 1903.

Rain forest is the evergreen forest characteristic of warm tropical regions with a heavy rainfall and high atmospheric humidity. The rainfall is at least 200 cm. (about 80 in.), but is often much greater. The dry season is usually not prolonged, or where there is a prolonged dry season this forest occupies moist situations. The vegetation is luxuriant, the forest often consisting of two or more tiers, the trees of the highest tier being at least 100 ft. high and often much taller. The species are very numerous, and are chiefly or entirely evergreen; gregariousness is strikingly absent. Many of the trees have plank buttresses at the base; they have as a rule comparatively thin smooth bark and are only sparingly branched. The leaves are of very diverse forms, often firm, leathery, and glossy, seldom finely pinnate or with a thick covering of hairs. The forest is rich in thick-stemmed climbers, climbing palms, and woody as well as herbaceous epiphytes. Tropical rain forest is well developed on the west coast, in the moister parts of Burma, in Chittagong, Arakan, the Andamans, and the eastern sub-Himalayan tract and lower hills.

Monsoon forest occurs in regions where the rainfall exceeds 180 cm. (about 70 in.) but where there is a prolonged dry season. The forest is more or less leafless during the dry season; the trees are tropophilous in character and usually less lofty than in rain forest. This forest is rich in woody climbers and herbaceous epiphytes, but poor in woody epiphytes. The typical monsoon forest of Schimper's definition comprises the moister and more luxuriant forms of mixed deciduous forest which are well developed in the west coast region, in the moister parts of the sub-Himalayan tract, and in Assam, Chittagong, Arakan, Burma, and the Andamans. In the Indian region, however, monsoon forest answering the description in every respect occurs in regions with a rainfall of not more than 50 in., and perhaps as low as 40 in.; such forest is well developed in the sub-Himalayan tract east of the Jumna, as well as in parts of Chota Nagpur, Orissa, the Central Provinces, the Circars, and other localities.

Savannah forest is more or less leafless during the dry season, rarely evergreen: it is open and park-like in appearance, very poor in undergrowth, climbers, or epiphytes, and rich in terrestrial herbs, especially grasses. The trees are xerophilous in character and are usually less, often much less, than 65 ft. high. This formation comprises many different types of forest in India, including the opener types of mixed deciduous forest in the Peninsula, the sub-Himalayan tract, and Burma, as well as open grassy types of sal forest and of Burmese *indaing* forest.

Thorn forest is similar to savannah forest as regards foliage and height of trees, but is more xerophilous. Thorny plants are always plentiful; the forest is rich in underwood and slender-stemmed climbers, but poor in terrestrial herbs, while epiphytes are usually absent. Thorn forest is well developed in the drier parts of the Indian Peninsula and the sub-Himalayan tract, in the semi-desert regions of north-western India, and in the dry zone of Upper Burma.

Among the tropical woodland formations of minor importance may be mentioned the xerophytic evergreen bush forest of the Carnatic region: this formation is characteristic of localities where the rainfall is small but where there is no prolonged dry season.

At temperate elevations climatic formations of a different kind are met

with. Temperate rain forest, which occurs in cool regions with a heavy rainfall, resembles tropical rain forest in general character, being hygrophilous and largely evergreen, though less luxuriant and not so rich in species: magnolias, laurels, and other evergreens are characteristic. This formation is developed at moderate elevations in the eastern Himalaya and in the moister hill regions of southern India, Assam, and Burma. In the eastern Himalaya above the rain forest the vegetation becomes tropophilous, many of the trees losing their leaves in winter. In the western Himalaya no true rain forest is found: the climate is drier and the vegetation is tropophilous, or in the drier regions xerophilous.

Of the west Himalayan evergreen oaks *Quercus incana*, *Q. semecarpifolia*, *Q. Ilex*, and *Q. lanuginosa* show decidedly xerophytic characters in their stiff leathery leaves with a dense felty covering of hairs on the lower surface. The conifers, which are a characteristic feature of temperate elevations, particularly in the Himalaya, constitute special types of forest. Warming¹ states that evergreen conifers are pronounced xerophytes when judged by their morphology, anatomy, and physiological characters: Schimper, however, rightly points out that it is not admissible to consider all conifers as xerophytes. Coniferous woodland, so far as Indian temperate species go, may be regarded as either xerophilous or tropophilous; in the former class may be placed *Pinus longifolia*, *P. Gerardiana*, the junipers, and probably *Cupressus torulosa*, while among tropophilous species may be placed *Pinus excelsa*, *Cedrus Deodara*, *Abies*, *Picea*, and *Taxus baccata*.

(ii) *Edaphic formations.* Edaphic woodland formations, which are due primarily to soil conditions, are well represented in India. The most important soil factor, at all events so far as Indian formations are concerned, is undoubtedly water; the mechanical texture of the soil and subsoil is also of great importance, but this factor operates to a large extent in its relation to the water content of the soil. Thus a fine-grained clay absorbs water slowly, has a high water capacity—that is, it is capable of holding a large percentage of water in proportion to its volume—and owing to its impermeability has great retentive power; a coarse sand, on the other hand, has a low water capacity and quickly parts with its water. Certain special formations, for instance those on saline soils in arid regions and along the coast, are due to the presence of soluble salts in quantity. Among edaphic formations whose existence is obviously due to the presence of water are fringing forests along the banks of rivers or lakes; these forests are maintained by the infiltration of water in the soil, or in some cases by periodical inundation. Among the best examples are the riverain forests along the Indus in Sind, consisting of *Acacia arabica*, *Tamarix dioica* and *T. Troupii*, *Populus euphratica*, and *Prosopis spicigera*. All but the last named of these species are incapable of surviving long in this arid region away from the influence of the river water. Along the banks of rivers in the dry parts of the Deccan, again, *Acacia arabica* grows gregariously, and gradually disappears on the higher and drier ground away from the rivers. Among other species characteristic of the fringing forests along rivers are *Salix tetrasperma*, *Putranjiva Roxburghii*, and *Trewia nudiflora*. It is, however, not always safe to attribute the existence of riverain forests solely to the presence of water. The characteristic riverain forests of *Dalbergia Sissoo* and *Acacia*

¹ Eug. Warming, *Oecology of Plants*, Eng. ed., 1909.

Catechu in northern India appear to owe their existence not so much to the presence of water in the soil as to the favourable conditions for the germination of the seed and the development of the young plants which are met with in these open riverain tracts ; these conditions are loose porous soil, complete exposure to light, and absence of heavy weed-growth. This is apparent from the fact that these species thrive well in these regions away from rivers, and spring up readily, even in comparatively dry tracts, provided conditions for germination and development are suitable. Swamp forests are due to the presence of water, often more or less stagnant and lying in depressions on an impermeable soil. The mangrove formation of tropical littoral regions is a special form of swamp forest.

There are many edaphic formations in which water is the deciding factor, but where this factor is not obvious at first sight because it is governed by the mechanical texture of the rock and subsoil. In hill regions variations in the forest formation are observable with changes of aspect and configuration, where the underlying rock does not change ; the more xerophilous species occupy the hotter aspects and the drier ridges, while the more hygrophilous species occupy the cooler aspects and moister depressions. Soil-moisture, as affected by aspect and configuration, is thus an important factor in determining the forest formation, but it may induce other important factors, such as a luxuriant growth of weeds in the moister localities, producing a struggle for existence which favours the establishment of certain species against others. The nature of the underlying rock and of the soil and subsoil is often found to have a very decided influence on the forest vegetation, but investigation will often, if not in most cases, show that its capacity for absorbing and retaining moisture is the dominant factor which influences the forest vegetation.

In the region of the sal (*Shorea robusta*) the presence of this important gregarious tree is determined to a great extent by the hygroscopicity of the soil. In the sub-Himalayan tract it is invariably absent from the recent sand and shingle of dry river-beds as well as from swampy ground, while on loamy soils it becomes the dominant tree over large tracts. In the Indian Peninsula it is found on various geological formations, but is almost entirely absent from the Deccan trap, where its place is taken by the teak ; the soil overlying this rock is usually shallow, and in the dry season the amount of moisture retained in the soil and subsoil is insufficient for the survival of the sal. In a comparatively dry climate or situation, this species may be absent from a geological formation which it frequents in a moist climate or situation, and this applies to many other species.

In the South and Middle Andaman islands the relative distribution of evergreen forest and semi-deciduous padauk-bearing forest appears to be determined largely by the geological formation. The former occurs almost entirely on grey, usually soft, non-calcareous micaceous sandstone, while the latter is found chiefly on indurated clay and shale, conglomerate, crystalline limestone, and hard, coarse, often metamorphosed sandstone.

In the western Himalaya *Pinus longifolia*, a xerophytic species, is frequently found on quartzite, which is too dry to support the majority of species, and the presence of this rock in some localities determines the prevalence of the pine.

Laterite is an important geological formation in the Indian region, and

from our point of view is of particular interest in that it supports very special types of forest vegetation. This rock, which is common in tropical countries, is a silicate of alumina very rich in hydrate of iron, red or dark yellow in colour, and poor in nutritive substances. It dries rapidly, but this does not seem to be due always, as is sometimes stated, to great permeability. Diluvial laterite is certainly permeable, and in general the permeability depends on the degree of disintegration: hard laterite, however, dries quickly owing chiefly to the rapid run-off of water from its surface, and to the fact that the soil overlying it is usually shallow. Hard weathered laterite is particularly unfavourable to forest vegetation, though laterite which is partially decomposed or mixed with soil derived from the decomposition of other rocks is by no means unfavourable. The most characteristic forest occurring on laterite is the deciduous dipterocarp formation of Burma known locally as *indaing* and consisting of *Dipterocarpus tuberculatus*, *Shorea obtusa*, *Pentacme suavis*, *Buchanania latifolia*, *Melanorrhoea usitata*, and certain other characteristic trees (see under *Dipterocarpus tuberculatus*). In the Indian Peninsula one of the commonest trees on laterite is *Cleistanthus collinus*, which grows remarkably well where the rock is in a decomposing state; other species frequently found on this rock are *Phyllanthus Emblica*, *Buchanania latifolia*, *Terminalia tomentosa*, and *Chloroxylon Swietenia*, while *Gardenia lucida* occurs in some localities on a mixture of clay and laterite. On the west coast *Xylia xylocarpa* is found growing gregariously on laterite.

A special type of soil which is found over large tracts in the Indian Peninsula is that known as black cotton soil. Dark or nearly black in colour, and containing a large proportion of clay, this soil has great capacity for absorbing water like a sponge in the rainy season, while it shrinks in the dry season, with the result that it becomes traversed in all directions by deep cracks: it is frequently, but by no means invariably, associated with trap rock. Black cotton soil is one of the most important agricultural soils of India, the great bulk of the cotton crop being grown on it. It is, however, unfavourable to forest growth, and the number of tree species found on it is comparatively small. Among the more characteristic trees are *Acacia arabica*, *A. Catechu*, *A. leucophloea*, *A. eburnea*, *Butea frondosa*, *Ougeinia dalbergioides*, *Cassia auriculata*, *Dichrostachys cinerea*, *Balanites Roxburghii*, *Terminalia tomentosa*, *Zizyphus Jujuba*, *Soyimida febrifuga*, and among introduced species *Albizzia Lebbek* and *Azadirachta indica*. Teak in stunted form is sometimes found on this soil. When closed to grazing black cotton soil produces a heavy crop of grass, chiefly species of *Eragrostis* and *Paspalum*.

Calcareous soils are met with in various forms. Limestone rock usually has poor water-absorbing properties, particularly if it is weathered and has little depth of soil over it; in dry localities such rock supports xerophilous types of vegetation. The same applies to fine-grained calcareous soils deficient in organic matter, but where such soils are rich in organic matter and the climate is moist the vegetation becomes hygrophilous. Warming¹ points out that although the characteristics of the lime flora are clear and distinct the influence of lime upon vegetation has been over-estimated. He notes that it has been definitely established that the amount of lime in itself, in so far as it does not operate physically, cannot be the cause of differences

¹ *Op. cit.*, p. 58.

in the flora, for not only can calcicolous plants be cultivated in a soil poor in lime, but silicicolous plants can grow vigorously in pure lime-water if the aqueous solution be otherwise poor in dissolved salts; lime soils as a rule are rich in soluble mineral substances, and this excludes plants characteristic of minerally poor soils. It may be noted here that *Cupressus torulosa*, which is characteristic of limestone regions in the Himalaya, grows well when planted in ordinary loam on other geological formations. *Pinus longifolia*, on the other hand, may be regarded as essentially silicicolous, flourishing best on sandy soils, but nevertheless it grows naturally on hard limestone rocks in the outer hills of Hazara, although owing to the physical characters of the rock the growth is poor except on northerly slopes where there is some depth of soil; that limestone is not unfavourable to *Pinus longifolia* provided the rock is not hard and the overlying soil is not shallow, is evident from the fact that the tree grows well in parts of the Kumaun hills on limestone where the rock is sufficiently soft and the soil is not too shallow.

Pans of concretionary lime, often mixed with clay, known as *kankar*, are of common occurrence in India, and are particularly unfavourable to forest growth, the lime forming a hard solid mass resembling masonry, and by its physical condition preventing the free development of the roots of trees; the forest vegetation is of an open, stunted, and xerophytic character. Calcareous tufa is found occasionally in the sub-Himalayan tract in the form of moderately hard deposits not far beneath the surface, and here again the forest vegetation becomes open and stunted; *Bombax malabaricum* and *Hymenodictyon excelsum* are often characteristic species, while *Shorea robusta*, which may be abundant in the neighbourhood, avoids ground where these deposits are at all superficial.

Saline soils, other than those due to proximity to the sea, are characteristic of regions of high summer temperature combined with deficient rainfall. In the dry season moisture evaporates from the surface layers of the soil, and in time there forms an accumulation of saline substances which the scanty rainfall is insufficient to remove, while the saline solutions in the lower layers of the soil ascend by capillarity, forming on evaporation a whitish alkaline efflorescence on the surface of the ground. Salts may be produced by the decomposition of rock minerals *in situ* or may be transported from a distance in solution. The degree of salinity is particularly high in heavy clay soils where the drainage is bad and there is little percolation, or in places where an impervious layer in the subsoil prevents free drainage; in well-drained porous soil the salts are removed in solution. As the degree of salinity of a soil increases vegetation diminishes until the soil becomes quite sterile. The chief salts are sodium carbonate, sulphate, and chloride; all are harmful to plant life, though sodium carbonate is the most noxious. Among the few trees which will grow on soil with a moderate degree of salinity are *Acacia arabica*, *Prosopis spicigera*, *Tamarix articulata*, and *Butea frondosa*. More halophilous still is the shrub *Salvadora persica*, while in soil which is strongly saline and yet not quite sterile *Salsola foetida* and *Suaeda fruticosa* are characteristic. After heavy rain patches of strongly saline soil often become covered with a growth of the grass *Sporobolus arabicus*, Boiss., which dries up and disappears soon after the rain is over.

The most successful methods of reclaiming saline lands are those which aim at improved drainage. Where water is plentiful perhaps the most satisfactory method is to dig deep open drains dividing the land into fairly large sections and to heap the earth up in the form of bunds round the sections. Each section is then well flooded with water, which percolates through to the drains and carries away the salts in solution. Flooding has to be repeated as a rule several times. In the Kistna delta saline lands in proximity to the coast are reclaimed by puddling in large quantities of straw and then flooding with water; the straw assists drainage. Dressing the soil with gypsum (sulphate of lime) has proved effective in some cases, the gypsum reacting on the sodium salts and producing less injurious substances. As gypsum is scarce in India, however, this method is too costly for general application. A method of planting *Acacia arabica* and *Prosopis spicigera* on saline lands, which has been attended with some success, is described under *Acacia arabica*.

The different types of littoral woodland are edaphic formations of a very special kind; the component species are essentially halophytic owing to the saline nature of the soil, and exhibit xerophytic structures because of its physiological dryness. Below high tide there is no forest vegetation on sandy and rocky sea-shores, but in estuaries and lagoons and along tidal creeks is found the mangrove formation, a special type of evergreen forest which is unlike any inland formation, and of which the component species have leathery leaves exhibiting xerophytic structures. On the higher ground farther from the sea and exposed only to the influence of spring tides is found a different type of forest, usually termed 'tidal forest', in which the principal tree in the Sundarbans and the Burma coastal regions is *Heritiera Fomes*. The mangrove and tidal forests are described in some detail under Rhizophoraceae and *Heritiera Fomes*. The trees are characterized by the possession of special adaptations for resisting the force of the wind and the tides, in the shape of stilt-roots or of anchor-roots descending from the stem and branches; special adaptations for the aeration of the roots in the muddy ground in which these trees grow are seen in the form of superficial roots, sometimes ribbon-shaped, spreading along the surface of the ground or bending out of the mud in the form of knees, while some species send up pneumatophores resembling inverted tent-pegs. The trees of beach forests, on old raised sandy and stony beaches above the reach of high tide, often exhibit xerophytic leaf structures, especially towards the outer edge of the littoral belt; this is seen in the thick and leathery leaves of *Calophyllum Inophyllum*, *Terminalia Catappa*, and *Barringtonia speciosa*, the succulent leaves of *Scaevola Koenigii*, the scale-like leaves of *Casuarina equisetifolia*, and the leaves, covered with a gummy varnish, of *Dodonaea viscosa*.

The examples of edaphic formations just given will serve to illustrate some of the more marked types of forests which depend for their existence mainly on edaphic conditions. These do not include the many variations to be found in ordinary forest soils varying from stiff clay to pure sand, the relative proportions of which may exercise a decided influence on the composition of the forest crop. The presence of certain species of trees on stiff clay or on pure sand does not necessarily indicate their preference for such soils; in

many cases it indicates nothing more than their capacity for existing on them. Thus *Terminalia tomentosa*, *Butea frondosa*, *Stereospermum suaveolens*, and *Eugenia operculata* are often found on stiff clay, though they are by no means confined to it. *Dalbergia Sissoo* and *Acacia Catechu* grow freely on the pure sand and shingle of riverain tracts, but they thrive also on loamy soils, though the former species in particular will not tolerate heavy clay.

Abundant soil-moisture may have the same effect as reduction of temperature, a fact which is illustrated by the presence in moist localities in the sub-Himalayan tract, at elevations of about 2,000 ft. or even lower, of species which occur normally at temperate regions in the Himalaya at elevations of 4,000 to 8,000 ft. or more. Instances are *Quercus incana*, *Q. spicata*, *Celtis australis*, *Acer oblongum*, and *Hedera Helix*. The presence in such localities of temperate species is possibly due to the reduction of temperature consequent on active transpiration during the hot season, the loss of water being made good from the large supply available in the moist soil.

The importance of forest grasses as indicators of edaphic conditions has been demonstrated by Hole¹ in respect of the Dehra Dun valley and Saharanpur Siwalik tract. The oecological study of these grasses over defined tracts where the climatic conditions are constant will often lead to interesting and important results in demonstrating the suitability of different classes of soil for the growth of different species of trees, since there is often a marked parallelism between certain types of forest and of grassland respectively. Thus in the Dehra Dun and Siwalik tract the dominant grass on ground most favourable for the growth of sal is *Saccharum Narenga*. On dry shingle beds and in other places which are usually too dry to support sal, and on which forest of a dry mixed deciduous type is prevalent, the dominant grass is *Saccharum Munja*, while other common species are *Aristida cyanantha*, *Tri-raphis madagascariensis*, *Andropogon monticola*, and the dry form of *Saccharum spontaneum*: the parallel woodland formation on these dry shingle beds is forest of *Acacia Catechu* and *Dalbergia Sissoo*. In moist mixed forest, sometimes merging into swamp forest, *Erianthus Ravennae* is the dominant grass. *Imperata arundinacea* often denotes stiff badly drained clayey soil or denuded ground somewhat unfavourable to the growth of sal. *Phragmites Karka* and *Arundo Donax* are species indicative of ground which is too swampy for sal and for the great majority of trees; *Saccharum spontaneum* is also frequently prevalent on low-lying wet ground unsuitable for sal. *Anthistiria gigantea* frequents sal tracts, but may also indicate ground insufficiently drained for sal. Again, in the eastern sub-Himalayan tract, where the climate is moister, savannahs are of frequent occurrence. Here again the dominant grass on ground suitable for sal is *Saccharum Narenga*, and with it occur *Saccharum arundinaceum*, *Arundinella Clarkei*, *Erianthus fastigiatus*, and *Andropogon Nardus*. As before, *Imperata arundinacea*, though sometimes present on sal-bearing ground, may also indicate stiff badly drained clayey soil, while *Saccharum spontaneum* and *Anthistiria gigantea* may also be indicative of ground not sufficiently well drained for sal. *Phragmites Karka*, *Erianthus elephantinus*, and *Saccharum procerum* are characteristic tall grasses of the moist low-lying

¹ R. S. Hole, On some Indian Forest Grasses and their Oecology, Ind. For. Mem. Bot., Ser. i, i, 1911.

savannahs unsuitable for sal and supporting open forests of *Albizzia procera*, *Bischoffia javanica*, *Bombax malabaricum*, and other trees.

Similarly, bamboos are good indicators of varying soil conditions, and in countries like Burma, where they form an important adjunct to some of the principal types of forest, they are of special interest in this respect (see under *Tectona grandis* and *Bambuseae*).

SOIL CONDITIONS. In the foregoing account of some of the edaphic formations of India mention has been made of certain classes of soil which have a decided influence on the character of the forest vegetation. Although it will be impossible here to enter into a detailed consideration of the properties of soils, there are certain questions connected with the soil which closely affect the origin, the distribution, and the stability of various forest crops.

The question whether the chemical or the physical characters of the soil exercise a more decisive influence on the distribution of plants is one which has been discussed by many writers, some of whom have supported the one point of view and others the other. Although due weight must be given to the importance of chemical influences in certain classes of soil, nevertheless the basis of oecological classification is a physical one, namely, the water content of the soil, which is in turn influenced by its physical characters, such as depth, consistency, and capacity for absorbing and retaining water. Some modern writers have devoted special attention to the study of so-called soil solutions, in which the moisture in the soil is regarded as a medium by which nutriment is conveyed to the roots of plants. It is not sufficient that a soil should contain the elements necessary to support plant life; it is equally necessary that these elements should be in a condition suitable for absorption by the roots of plants, that is, they should be in solution. Many desert or semi-desert soils are rich in nutriment, but in their natural condition are incapable of supporting any but the most xerophilous vegetation, although if irrigated they yield abundant crops. Where the degree of concentration of a soil solution tends to vary through some external influence such as wetting and drying, the soil is said to be anastatic, whereas soils which remain more or less constant in this respect are termed eustatic. The soils of bare or ploughed land are more anastatic than those of grassland and forest. In the majority of soils conditions of anastatism exist mainly near the surface, and a soil may be converted from a eustatic to an anastatic condition by special treatment such as ploughing, mulching, manuring, or liming, thus promoting new chemical reactions or altering the moisture conditions.

The soil at a depth at which the roots of forest trees mainly receive their nourishment is eustatic. Anastatic conditions can be set up artificially in practice to a depth of a few feet by drainage, and to a greater depth by irrigation, but so far as is known there is no reliable evidence in India of any marked change, within a short period of time, of soil conditions at any considerable depth below the surface owing either to the draining or the moisture-conserving action of forest growth of recent introduction. There is, however, striking evidence of sudden change in the soil conditions at some depth below the surface in years of abnormal drought, when even the most deep-rooted trees are killed for want of moisture. In the abnormal drought of 1907 and 1908 in the forests of the alluvial plains of Oudh the subsoil water-level fell in varying

of seedling reproduction is closely connected with conditions of seeding and germination and with the requirements of the seedling. Vegetative reproduction, although of less importance generally, may have special significance under certain conditions. Not only is the study of natural reproduction an essential preliminary to the adoption of correct silvicultural treatment for different kinds of forest crops, but it also serves to elucidate many problems connected with such interesting and important questions as invasion, woodland succession, and gregariousness. As a preliminary to the determination of the several factors which affect the establishment of seedling reproduction in any particular instance, it will be found necessary to consider three separate stages leading towards the production of a young natural crop: these stages are (1) flowering and fruiting, including the dissemination of seed, (2) germination, and (3) the seedling. We may here consider briefly some points of interest connected with these stages.

Flowering, fruiting, and germination. In many cases, and perhaps in the majority, the fertilization of the flowers of Indian forest trees appears to be carried out by insect agency, for many of the trees when in flower are visited by swarms of bees and other insects, and the flowers are often perfumed or showy, or exude nectar. Important exceptions are to be seen in the case of the conifers, which are fertilized by the agency of the wind, and produce pollen in large quantities. Certain showy flowers, notably those of *Bombac* and *Erythrina*, are fertilized by birds; it is noticeable that such flowers have a tendency to be red in colour.

The dissemination of seed is a subject which concerns natural reproduction very closely. Some writers place a much higher value than others do on the efficiency of wind as a distributing agent. In most cases winged or light seeds and fruits certainly rely on wind as the chief distributing agent, but the extent to which distribution takes place in the case of each species is by no means easy to determine from casual observation. Under ordinary conditions the heavier winged fruits and seeds, for instance the fruits of dipterocarps, are not conveyed in quantity to any great distance from the trees. In the case of Indian conifers, the winged seeds of the pines—other than *Pinus Gerardiana*—and the spruces, which escape singly from the cones, are ordinarily conveyed to greater distances than are those of the deodar and silver fir, whose seeds fall with the cone-scales when the cones break up on the tree. In the case of some pines, notably *Pinus longifolia*, the cone-scales open gradually; the cones are attached to the branches at various angles, and the seeds are not dislodged in any quantity without the aid of a stiff breeze, which ensures their spread to some distance. Seeds, such as those of *Bombax*, *Populus*, and *Salix*, which are embedded in silky down are carried by wind over considerable distances.

Water is the natural distributing agent of seeds of species growing in littoral regions. The fruits or seeds of such species often have special adaptations for floating, usually in the shape of floating tissue. *Terminalia Catappa* has floating tissue in the fruits, *Carapa moluccensis* has a large fleshy seed with a thick fibrous testa, *Sonneratia apetala* has a globose fleshy buoyant fruit, *Avicennia officinalis* has a large buoyant capsule, and *Heritiera Fomes* has a large starchy seed with a cavity between the cotyledons which ensures its

buoyancy. Among inland species which are frequently found near streams and of which the fruits are buoyant, may be mentioned *Dillenia indica*, with large globose fruits the outer portion of which is formed of the persistent fleshy sepals, and *Trewia nudiflora*, with globose fruits having a fleshy mesocarp of floating tissue. Many of these water-borne seeds ripen during the rainy season when the streams are swollen, and this aids greatly in their dissemination. This applies not only to *Trewia nudiflora* but also to littoral species, for instance *Excaecaria Agallocha*, *Heritiera Fomes*, *Carapa moluccensis*, *Sonneratia apetala*, *Avicennia officinalis*, and others.

Birds and fruit-bats are disseminating agents in the case of many fleshy fruits. The effect of bird agency is nowhere more marked than in the case of the numerous species of *Ficus*, several of which start life as epiphytes in the forks or cavities of tall trees. Birds in some cases probably carry seeds to a considerable distance, as in the case of *Lantana*, and it is often difficult to account for the appearance in certain localities of isolated specimens of trees—for instance, *Carallia lucida* in parts of the sub-Himalayan tract—except by attributing it to the agency of birds.

Apart from their agency in effecting this dissemination of seeds, as in the case of *Zizyphus Jujuba*, *Spondias mangifera*, and other species, animals may exercise an important function in facilitating their germination. If the fruits of *Aegle Marmelos* are not opened by pigs, deer, and other animals the seeds usually, if not always, decay or are destroyed by insects before escaping from the fruit. Perhaps the most remarkable instance so far observed of such animal aid is that of the opening of the pods of *Cassia Fistula* by jackals, monkeys, and other animals, without which it is doubtful if the seed ever germinates before it is destroyed by insects. Seed of *Acacia arabica* ejected by goats and other animals which have eaten the pods germinates more freely than that which has not undergone this treatment. The assistance given by termites to the germination of *Dillenia indica* seed is described in dealing with that species.

Birds and animals, on the other hand, may exercise an adverse influence on natural reproduction by destroying seed in quantity; for instance, jays, nutcrackers, and flying squirrels at times do much harm in this respect in the oak and conifer forests of the Himalaya.

In many cases the nature of the seed indicates not only the conditions under which germination is facilitated or rendered possible but also the demands of the seedling. The seeds of many species which stand shade or require moisture in youth or later are large, heavy, and often smooth and rounded; such seeds tend to roll into moist depressions and ravines where the requirements of the young plant are provided for. Such are the seeds of *Mesua ferrea*, *Dysoxylum* spp., *Amoora Rohituka*, *Calophyllum* spp., *Aesculus indica*, and others. On the other hand, small light or winged seeds and fruits, which are disseminated far and wide, germinate freely on newly exposed mineral soil, and the seedlings require open places for their development and survival; accordingly natural reproduction springs up readily on landslips, abandoned cultivation, newly formed deposits in river-beds, areas recently overrun by fire, and similar places. Species belonging to this category, which are often, but not invariably, strong light-demanders, include *Tamarix* spp., *Cedrela* spp.,

Bucklandia populnea, *Dalbergia Sissoo*, *Terminalia myriocarpa*, *Anogeissus latifolia*, *Woodfordia floribunda*, *Wendlandia exserta*, *Anthocephalus Cadamba*, *Adina cordifolia*, *Stephegyne parvifolia*, *Duabanga sonneratioides*, *Rhododendron arboreum*, *Macaranga* spp., *Trema* spp., *Betula* spp., *Alnus* spp., *Salix* spp., *Populus* spp., *Casuarina* spp., and conifers with winged seeds. In the case of most seeds other than those of minute size or light weight, a covering of earth or débris greatly assists germination, and may be essential in dry situations in the case of seeds which ripen and fall some time before the beginning of the monsoon ; this covering is commonly effected by the action of rain, and is greatly facilitated in loose soil.

The monsoon is the natural season for germination in the case of the great majority of Indian species, and seeds which are quickly perishable fall during or at the commencement of this season and germinate at once ; this is seen in the case of the Dipterocarpaceae, *Mangifera indica*, *Eugenia Jambolana*, *E. operculata*, and many littoral species. Many seeds whose vitality does not last many months fall some little time before the monsoon and germinate when it begins. Some seeds, particularly those which are hard or are enclosed in a hard putamen, retain their vitality for at least a year, and under natural conditions frequently lie dormant for that period or longer. Such are the seeds of many Leguminosae, including *Cassia Fistula*, *Bauhinia malabarica*, *B. racemosa*, *B. purpurea*, *Acacia arabica*, *A. Farnesiana*, *Prosopis spicigera*, *Albizia Lebbek*, *A. procera*, *A. stipulata* and other species, *Zizyphus Jujuba*, *Z. Xylopyrus*, *Sapindus detergens*, *Spondias mangifera*, *Gardenia turgida*, *Diospyros Melanoxylon*, *D. tomentosa*, *Cordia vestita*, *Tectona grandis*, *Fraxinus excelsior*, and *F. floribunda*. The seeds of the teak (*Tectona grandis*) are known to lie dormant in the ground sometimes for years.

The seedling. The seedling represents the most critical stage in the life of a tree. Conditions for seeding and germination may be entirely favourable, and natural seedlings may appear in countless quantities at the beginning of the rainy season, only to disappear largely or entirely within a comparatively short period of time owing to various causes, such as drought, bad soil-aeration, competition with weeds, shade, or other factors. Such a holocaust, which is a regular event in the case of many species, does not occur to the same extent throughout the life of an established crop after the seedling stage is passed, except for very special reasons such as the occurrence of abnormal drought. If the requirements of the seedling of any species are well understood the problem of the natural reproduction of that species is to a great extent solved, while the subsequent treatment of the crop is usually a comparatively simple matter. The whole system of management of a forest crop is fundamentally influenced by the steps necessary to establish reproduction, and it will therefore be readily realized that no branch of silviculture is of more importance than the study of the requirements of the seedlings of forest trees. Again, as will be explained below, problems of invasion, succession, and gregariousness have to be approached from the point of view of the seedling, for it is the establishment of the young plant that determines to a great extent, if not wholly, the occurrence of existing forest crops of various types, and in like measure regulates the transition from one type to another from place to place or during the course of time.

The size or form of the seedling often indicates the condition under which it passes its existence. In the case of many species with minute seeds the seedlings themselves are minute in their earlier stages, and in such cases an essential condition for their establishment is that they should spring up on clean and preferably porous soil, since owing to their minute size any competition or obstruction will prevent their development and establishment. Such seedlings are those of *Anthocephalus*, *Adina*, *Stephegyne*, *Duabanga*, *Rhododendron*, *Populus*, and others. A remarkable instance of the adaptation of the seedling to a special environment is to be found in the case of certain littoral species, for example *Carapa moluccensis* and *Heritiera Fomes*. The large fleshy cotyledons, which remain within the testa, are full of starchy nutriment. On germination a long leafless stem, resembling that of asparagus, and bearing only abortive scaly leaves, shoots up rapidly and attains a considerable length before any foliage leaves are produced. The nutriment in the cotyledons is thus employed for the rapid production of a stem which will elevate the foliage leaves above the level of the water which floods the ground periodically. Under natural conditions the seedling of *Quercus semecarpifolia*, the high-level oak of the western Himalaya, as a rule produces a shoot which remains leafless during the first season. Germination takes place about July, and a short growing season is followed by a period of autumn drought and a severe winter : the seedling therefore at once assumes a leafless winter form in order to withstand the climatic rigours to which it is exposed. A straggling branchy form in the seedling, often accompanied by the production of a long wiry taproot, is usually indicative of xerophytic habits, and may be seen in the case of seedlings of *Prosopis spicigera*, *Acacia* spp., *Zizyphus Jujuba*, and *Z. Xylopyrus*.

It is a well-known fact that in plants generally the amount of transpiration depends largely on the extent of the evaporating surface, that is, on the size of the leaves, as well as on their texture and disposition. The effect of external factors is clearly exhibited in the variation in the size of the leaves of seedlings of one and the same species, which is usually greater than in the case of adult trees. In many parts of India, however, perhaps the most important attribute of the seedling is the development of the root-system, since seedlings have to contend against the adverse influence of a long dry season, and the deeper the penetration of the root the less the risk of failure of the requisite water-supply during periods of drought ; hence the importance of any measures which can be taken to promote a strong root-system during the first few months in the life of the seedling. Under conditions sufficiently far removed from the optimum, one of Nature's methods of assisting the survival of seedlings is to provide for the dying back, in whole or in part, of the stem of the young plant. This dying back often takes place for several years in succession, new shoots being produced year after year from the living tissues below the dead portion of the stem, usually from the collum. Meanwhile the root develops steadily, pushing its way down until it has established itself sufficiently, after which the stem ceases to die back and commences upward growth. The commonest cause of dying back is drought, since the phenomenon is seen most frequently in dry regions, where it takes place in the dry season ; in this case dying back ceases when the root has penetrated to

strata moist enough to make good the loss of moisture by transpiration. In the case of *Shorea robusta*, and possibly of other species also, another fruitful cause of dying back is bad soil-aeration operating during the rainy season (see under *Shorea robusta*). Dying back may also be the result of frost damage. The production at an early age of a strong taproot, with few or no lateral roots, appears to be a characteristic of seedlings which die back. The phenomenon is perhaps commoner than is usually supposed, and under certain conditions is characteristic of such widely different species as *Shorea robusta*, *Bombax malabaricum*, *Pterocarpus Marsupium*, *P. santalinus*, *Butea frondosa*, *Hardwickia binata*, *Bauhinia racemosa*, *Acacia Catechu*, *A. Senegal*, *Terminalia tomentosa*, *Eugenia Jambolana* var. *caryophyllaefolia*, *Diospyros Melanoxyton*, *Santalum album*, *Tectona grandis*, and *Quercus semecarpifolia*.

Vegetative reproduction. In many species the production of suckers is an important aid to the perpetuation of the species, particularly in dry localities where conditions for seedling reproduction are adverse. One of the most noteworthy examples of this is seen in the case of *Prosopis spicigera* in the arid regions of north-western India, where seedling reproduction is incapable of establishing itself except in riverain areas and moist depressions; nevertheless on the more elevated and drier ground *Prosopis* survives, and has apparently survived for long periods of time, by means of sucker reproduction. This form of reproduction appears to be common in dry situations, though it is by no means confined to such places. Certain species, notably *Diospyros Melanoxyton* and *D. burmanica*, are remarkably tenacious of the ground they occupy owing to the vigour of their sucker reproduction: where they are present they are among the last species to disappear when land is cleared for cultivation, and land which has been cultivated for a few years and then abandoned becomes covered with sucker growth of these trees. There are certain other species which are nearly if not quite as tenacious, for instance *Butea frondosa*, *Ougeinia dalbergioides*, *Acacia dealbata*, and others. Among bamboos *Melocanna bambusoides* displays similar tenacity in the manner in which culms are sent up from portions of the rhizomes left in the ground on land cleared for cultivation. The list of species producing suckers is a long one. Certain natural orders exhibit a striking tendency to reproduce in this way, notably the Leguminosae (*Dalbergia*, *Ougeinia*, *Butea*, *Cassia*, *Xylia*, *Prosopis*, *Dichrostachys*, *Albizzia*, some species of *Acacia*, and many others), the Rosaceae, and the Bignoniaceae (*Stereospermum*, *Heterophragma*, *Millingtonia*, *Oroxylum*).

Vegetative reproduction is not confined to the continuance of the species by means of suckers, but may be taken to include also the power to persist by means of new shoots from the base or otherwise when coppiced or when subjected to cutting, lopping, burning, browsing, or other forms of injury. This power is possessed to a considerable degree by the teak, which in parts of the Indian Peninsula is sometimes almost the sole survivor in areas subjected to every form of maltreatment.

INVASION, SUCCESSION, AND GREGARIOUSNESS. Even to the most casual observer the fact is often brought home that certain types of forest are of a temporary kind, and after occupying the ground for varying periods of time give way in the natural course of events to other types, this

change being sometimes accelerated by a change in external conditions. A study of these changes is of great importance to the forester, for an appreciation of their significance will often afford an indication of the kind of forest crop which can be grown in a given locality. It may be said in general that every existing natural forest crop has been brought into being by a process of invasion, followed in many cases by succession, the struggle for existence determining its composition to a large extent. 'Invasion' has been defined as the movement of plants from one area to another of a different character and their establishment in their new home. Among examples of invasion may be mentioned the following: (1) *Macaranga* springing up and establishing itself on savannahs with the introduction of fire-protection; (2) *Dalbergia Sissoo* and *Acacia Catechu* growing up on recently formed shingle deposits in the beds of rivers; (3) mangroves taking possession of newly formed mud flats in littoral regions; (4) mulberry appearing through the agency of water, and spreading through the agency of birds, with the introduction of irrigation in the Punjab plains, where the pre-existing vegetation is of a semi-desert character; (5) various species with small light seeds—*Woodfordia*, *Duabanga*, *Wendlandia*, *Trema*, and others—springing up on landslips and other places where the soil has been recently exposed. Among exotic plants introduced by man which have become invasive to a troublesome degree may be mentioned *Lantana aculeata*, *Eupatorium odoratum* in Burma, *Opuntia Dillenii* (prickly pear) in dry regions, *Mimosa pudica* (sensitive plant) on pasture lands, and *Eichhornia Crassipes* (water hyacinth) in creeks and tanks.

'Succession' is the term applied to a series of invasions occurring in the same place. It is generally divisible into three stages: (1) the initial stage, in which certain species of trees, usually with small, light, or winged seeds, take possession of recently formed or newly exposed ground; (2) the transitional stage, in which changes take place on ground already clothed with some sort of vegetative cover; and (3) the climax stage, which represents the farthest advance towards a hygrophilous type of vegetation which the locality is capable of supporting. On this basis tropical evergreen forest, which probably represents the climax vegetation in humid regions, and persists as such as long as external conditions remain unaltered, may be regarded as the highest type of woodland formation, and succession which proceeds from a xerophilous to a more hygrophilous type is termed 'progressive succession'. The reverse process, in which a more highly developed formation, which may be hygrophilous or mesophilous in type, reverts to a simpler or more xerophilous type, is known as 'regressive succession': it is exemplified by the gradual deterioration of forest through fire, grazing, or otherwise, the more sensitive species giving place to the hardier and more xerophytic species. 'Parallel succession' is the term applied to a change from certain types of grassland to parallel types of woodland, and vice versa. This parallelism between certain species of grass and trees respectively has been demonstrated by Hole¹ in the case of the Dun and Siwalik tracts: of xerophytic forms the grass *Saccharum Munja* has its counterpart in the tree *Acacia Catechu*, while of mesophytic forms the grass *Saccharum Narenga* has its counterpart in the tree *Shorea robusta*. In the savannah tracts of the Duars marked parallelism is to be observed between

¹ *Op. cit.*

grassland and woodland species. Here on the high-level savannahs whenever the dominant grass is *Saccharum Narenga* the most characteristic tree is *Shorea robusta*. On the moist low-level savannahs these two species are unable to exist; here the dominant grasses are *Saccharum procerum*, *Phragmites Karka*, and others, while among the characteristic trees are *Albizzia procera*, *Bischoffia javanica*, and *Bombax malabaricum*. Grasses are in this respect particularly good soil-indicators, for owing to the perfect adaptation of their light seeds for dissemination far and wide they are among the first plants to spring up in abundance on new ground, and the presence of certain species of grass on such ground will often indicate the tree species which the ground is capable of supporting, and which will almost inevitably make their appearance in due course. Parallel succession is similarly to be observed between certain species of bamboos and trees: in Burma this parallelism is particularly marked between the bamboos *Bambusa polymorpha* and *Cephalostachyum pergracile* on the one hand and the trees *Tectona grandis*, *Xylia dolabriformis*, and their associates on the other, and the conditions which enable these two species of bamboo to thrive may be regarded as equally suitable for the growth of the trees mentioned.

Before proceeding to consider some examples of woodland succession it will be of interest to determine what fundamental grounds exist to explain why changes occur in forest formations and associations. So far as India is concerned it may be said at once that there is no evidence to show that any changes in the forest vegetation are attributable to changes in rainfall conditions within recent times. Dr. Walker¹ has produced evidence to show that there has been no radical change in the rainfall of India since 1841, and to lead to the inference—based on records, dating from 1737, of Nile floods arising from rainfall in Abyssinia, to which the Indian rainfall has a strong affinity—that there has been no radical change in the Indian rainfall since 1737. This naturally does not include sudden changes in the vegetation which may occur owing to the effects of abnormal drought; in such cases regressive succession might result.

Woodland succession in India, then, must ordinarily be explained on grounds other than climatic, since temperature statistics likewise do not reveal any radical changes. Provided external conditions remain unchanged, a formation may possibly retain its character for an indefinite period. This is probably the case not only with tropical evergreen forest but also with many types of deciduous forest. Nevertheless the equilibrium of a formation is often highly unstable, and the slightest change in external conditions may result in a corresponding change in the vegetation. It is not always sufficiently realized that in the great majority of cases this change takes place through a change in the conditions under which the existing vegetation had its origin, that is, the conditions under which the seed is able to reach the ground and germinate and the seedling is capable of establishing itself have undergone some radical alteration. This being so, whatever may be the external stimulus which leads to a change in the type of forest, the reasons why such a change has been brought about as a result of such a stimulus cannot be determined

¹ Gilbert T. Walker, On the Meteorological Evidence for supposed Changes of Climate in India, Mem. Ind. Met. Dept., vol. xxi, pt. i, 1900.

without a close study of the requirements of the seedlings of the species concerned. Changes in external conditions may be brought about in various ways. Frequently the change takes place by reason of conditions (moisture, shade, &c.) produced by the formation itself: it may also be brought about by river action or other forms of erosion and deposition, by grazing, fire, or the direct action of man. In some types of forest the equilibrium of the existing vegetation is maintained by the action of annual forest fires, and some remarkable cases may be observed of a complete alteration in the type of forest brought about through the introduction of fire-protection in areas previously subjected to regular burning. Succession in such cases is progressive, the succeeding type of forest being more hygrophilous than the pre-existing type. Examples of progressive succession due to the introduction of fire-protection will be found under *Shorea robusta* (vol. i, pp. 71-3), *Tectona grandis* (vol. ii, pp. 724-8), *Macaranga denticulata* (vol. iii, p. 848), and *Cedrus Deodara* (vol. iii, p. 1107). In all these cases it will be found that an alteration in the type of forest has been brought about by a change in the conditions under which seedlings of the pre-existing type are capable of establishing themselves, this change being directly attributable to the introduction of fire-protection. In the case of sal in the Duars continued fire-protection has produced soil conditions unfavourable to the establishment of sal seedlings but favourable to the establishment of various evergreen species with which the sal is unable to compete, and the process to be observed in these conditions is one of gradual succession from sal forest to an evergreen type devoid of sal: in this case unfavourable soil conditions, rather than want of light, appear to be the primary cause of the change of type, since the admission of light has proved to be ineffective in bringing about the establishment of sal seedlings.

The case of teak in Burma is probably somewhat different, though the factors which prevent the establishment of teak seedlings in the moister types of fire-protected forests have not been so fully studied as in the case of the sal. In many cases fire-protection in the teak forests of Burma has resulted in an excessively dense growth of bamboos, the natural companions of the teak; this suggests parallelism, with soil conditions not unfavourable to the establishment of teak seedlings, in which case the failure of the teak to establish itself is probably due to competition with the bamboos and want of light. In many cases the competitors of the teak, as a result of the introduction of fire-protection, are fast-growing softwoods or evergreen species, which frequently form a dense undergrowth. The factors preventing the establishment of the teak may be various, but among reasons which alone are sufficient to account for it are the failure of teak seed to germinate on ground which is not exposed to the heat of the sun, and the inability of young teak plants to struggle against heavy undergrowth or to survive under dense cover. In moist regions progressive succession, even without the stimulus of fire-protection, is sometimes revealed by the presence of large teak trees standing in dense evergreen forest. From a knowledge of the requirements of teak seedlings the idea that the teak trees originated in that type of forest may be at once dismissed: they must have started life either in the open or in a deciduous type of forest of no great density, and the evergreen forest must

have encroached on the ground subsequently, probably under the stimulus of conditions of soil and shade produced by the pre-existing deciduous forest.

Numerous other instances of progressive succession consequent on the introduction of fire-protection might be quoted from almost every part of India. Not the least interesting is that in which *Cedrus Deodara* is succeeding *Pinus longifolia* in certain parts of the western Himalaya where the zones of these two trees adjoin. Another interesting case is that in which burnt savannah lands in the eastern sub-Himalayan tract, on which the characteristic trees are fire-resisting species such as *Shorea robusta*, *Careya arborea*, *Dillenia pentagyna*, and *Bombax malabaricum*, on the introduction of fire-protection become rapidly occupied by quick-growing short-lived species such as *Macaranga denticulata*, *Trema orientalis*, and *Callicarpa arborea*; these are succeeded by mixed deciduous forest, which finally gives place to evergreen forest, though in the moister localities the deciduous stage may be wanting, while in the drier localities the evergreen stage may not be reached.

Progressive succession in riverain areas is well illustrated in the sub-Himalayan tract. New deposits of sand and shingle in the beds of rivers become occupied first by certain grasses in open clumps, of which the most characteristic are *Saccharum Munja*, the sand form of *S. spontaneum*, and *Triraphis madagascariensis*. Tree vegetation in the shape of gregarious crops of *Dalbergia Sissoo* and *Acacia Catechu*, sometimes preceded by *Tamarix dioica*, soon makes its appearance; the seedlings of these species are light-demanding and intolerant of weed-growth, while their growth is specially favoured by a porous soil with sufficient subsoil moisture, and these are the conditions which they encounter in these open clean porous shingle-beds, where subsoil moisture is obtained by percolation. After the crops of *Dalbergia* and *Acacia* establish themselves, an undergrowth of *Adhatoda Vasica* or other shrubs frequently makes its appearance: this, combined with the shade of the overhead trees, produces conditions which render it impossible for the *Dalbergia* and *Acacia* to reproduce on the same ground, for although seedlings of these trees are often found in quantity under the parent trees early in the rainy season, these soon die off. New species, however, make their appearance, and in time the forests change to a mixed deciduous type with such trees as *Bombax malabaricum*, *Odina Wodier*, *Garuga pinnata*, *Holarrhena antidysenterica*, *Ehretia laevis*, and others, with *Acacia Catechu* and *Dalbergia Sissoo* occasionally persisting or even reproducing where the ground is sufficiently open and clean. In course of time with the gradual accumulation of vegetable debris and the action of earthworms and other agencies the upper strata of the alluvium become gradually altered from sand and shingle to loam with a water content sufficient to allow of the establishment of sal seedlings, and the mixed deciduous forest may eventually give place to sal forest. This particular succession is not the invariable rule, but it is distinctly traceable in some localities.

The succession which takes place on the alluvial tracts along the Indus in Sind is of a regressive nature. On recently formed alluvium two species of *Tamarix* are usually the first woody species to make their appearance. These are followed by *Acacia arabica* and *Populus euphratica* on alluvium still subject to river floods, while later, on land elevated above the reach of all but abnormal

floods, *Prosopis spicigera* appears. Finally, on the highest and driest ground of all, these trees give place to semi-desert species, namely *Capparis aphylla*, *Salvadora oleoides*, and *S. persica*. This regressive succession is due to the gradual failure of the water-supply in an arid climate.

No better examples of regressive succession due to the action of man are to be found than in places where shifting cultivation is carried out. In the *ghat* forests of Coorg there is every reason to assume that the existence of deciduous forest is due to the practice of shifting cultivation formerly carried out on an extensive scale. The local conditions appear to be the same for evergreen and deciduous forests, but fire is very destructive to the former, and wherever shifting cultivation with the attendant burning is known to have been practised, deciduous forest is now present. In many of the hilly tracts of Burma, Chittagong, and Arakan shifting cultivation has converted tree forest into pure bamboo forest of a parallel type.

These examples of succession will suffice to indicate the great importance of a correct understanding of the causes leading to it in each individual case. In almost every locality changes in the type and composition of the forest crops are to be observed in progress, and the term 'rotation of crops' has been somewhat loosely applied. This term, as applied to forest crops, is scarcely analogous to the term as applied to agricultural crops, where it denotes temporary exhaustion of the soil so far as one crop is concerned and the necessity for growing another form of crop in succession to it. On the other hand, so far as evidence in India goes at present, if no radical alteration in the subsoil has taken place—as in the case of the riverain forests of Sind—there seems to be no reason why ground which at present supports a healthy crop of trees should not continue to support a healthy crop of the same species provided the seedlings are able to establish themselves successfully. But in speculating as to the reason for the failure of a crop to regenerate under itself it is sometimes forgotten that existing conditions for regeneration may be totally different from those which prevailed at the time the crop came into being. In some cases this may be due to altered soil conditions. Normally any changes which have taken place in the soil are confined to the surface layers, which are anastatic, and do not extend to the subsoil, which is eustatic: they therefore affect the roots of seedlings rather than those of the larger trees. Conditions favourable for the establishment of the seedling can often be created artificially by opening or completely removing the canopy and clearing and burning the undergrowth, while if the soil has been brought into an unsatisfactory state of aeration it may be necessary to cultivate field crops for a year or two. In the sal forests of the Duars, in the teak forests of Burma, and in the deodar forests of the western Himalaya such treatment has proved entirely successful in effecting the establishment of reproduction—which may have to be induced artificially—in places where none was capable of establishing itself under the old crop.

Gregariousness is closely connected with conditions of seeding and reproduction as well as with the struggle for existence. Gregariousness due to specially favourable conditions of seeding and germination is to be seen in the case of many species which rapidly take possession of newly exposed ground owing to the production of small, light, or winged seeds. Among trees those

with small light seeds, such as *Macaranga*, *Wendlandia*, *Trema*, *Alnus*, *Tamarix*, and others, as well as pines and other conifers with winged seeds, owe their gregariousness largely, and in some cases entirely, to conditions favourable for seeding and germination.

As a general rule the more favourable a locality is for vegetation the greater the number of species struggling for existence in it, and here gregariousness is the exception rather than the rule: this is well illustrated in tropical evergreen forest. But even here cases may occur in which some special advantage possessed by one or a few species over the others may enable them to regenerate in masses, and gregariousness may result over areas of greater or less extent. In localities where conditions for plant life are more or less adverse the struggle for existence between species is small or absent, and gregariousness may result through the absence of competition and the capacity of one or a few species to grow under unfavourable conditions. This probably accounts largely for the gregariousness of certain species in dry localities, for instance *Anogeissus pendula*, *Prosopis spicigera*, and *Boswellia serrata*, or at high elevations, for instance *Betula utilis* and *Juniperus* spp. Certain types of soil or geological formation, in producing conditions adverse to most species and thus favouring one or a few species, may cause gregariousness; this accounts in part for the gregariousness of *Dipterocarpus tuberculatus* on laterite, *Pinus longifolia* on quartzite and other dry formations, *Acacia arabica* on black cotton soil, and *Butea frondosa* on badly drained ground. Vegetative reproduction may account in some cases for gregariousness. In arid regions *Prosopis spicigera* may rely entirely on sucker reproduction to maintain its existence, and may become the sole survivor owing to this power. In certain tracts *Aegle Marmelos* forms pure forests on stiff clay, and on this unfavourable ground it probably owes its persistence largely to its power of reproduction from suckers. *Diospyros Melanoxylon* is at times also gregarious owing to its power of reproduction from suckers, while teak sometimes becomes gregarious as the sole survivor in forest subjected to lopping, cutting, and burning, owing to its remarkable power of endurance. Gregariousness is often due to immunity from damage by grazing, which favours certain species at the expense of others. Among species favoured in this way are *Butea frondosa*, *Holarrhena antidysenterica*, *Casearia tomentosa*, *Lagerstroemia parviflora*, *Woodfordia floribunda*, *Gardenia* spp., *Strychnos Nux-vomica*, *Clerodendron infortunatum*, *Adhatoda Vasica*, and many Euphorbiaceae, including *Cleistanthus collinus*, *Mallotus philippinensis*, *Sapium sebiferum*, *S. insigne*, *Jatropha Curcas*, and *J. gossypifolia*. Gregariousness is sometimes characteristic of some peculiar habitat tenanted by only a few species adapted for existence in it, as in the case of mangrove and tidal forests.

In many cases, however, gregariousness may be due to a combination of factors, some of which have been mentioned, the complexity of which may render it difficult to explain the precise cause in each case. The exact reason for gregariousness in the sal is by no means easy to determine. In favourable years seed is produced in vast quantities, its germinative power is high, and the ground is carpeted with young seedlings; these die off in quantity, but nevertheless under conditions which are at all favourable many survive, and once established these have the power of persisting for a considerable time under moderate shade and of recovering from the effects of fire, frost, and other forms

of injury. These are at least some of the factors operating to produce the characteristically gregarious sal crops. Among the dipterocarps generally gregariousness is characteristic of the more xerophilous rather than of the more hygrophilous species (see introduction to Dipterocarpaceae).

Gregariousness does not necessarily indicate the most favourable conditions for growth. In some of the dry areas of the Indian Peninsula teak is so plentiful as to be almost gregarious, but it is of small size compared with the teak found scattered in mixture with many other species in the forests of Burma and the Western Ghats. *Hardwickia binata* is more gregarious on trap than on sandstone and granite; yet on the former it is of comparatively small size, while on the latter, though more scattered, it reaches larger dimensions. *Butea frondosa* is sometimes gregarious on badly drained ground, but the growth is poor. *Pinus longifolia* often reaches a large size in mixture with *Quercus incana* on fertile soil, while on the poorest soils in the region of the pine it is often the only species that will exist, though it is stunted on such ground.

Although gregariousness is of special advantage to a species in its struggle against other species, it does not follow that it is the direct outcome of a preference for a social life, as is sometimes imagined. It is nothing more than the effect produced by certain conditions which specially favour a species in its reproduction and subsequent struggle for existence. For this reason a species may be gregarious in one place and not in another. Even the teak in Burma, which is a typically sporadic tree, sometimes springs up gregariously on abandoned temporary cultivation in places where teak seed-bearers are present. This is due largely to the fact that teak seed retains its vitality for years, and an accumulated supply of seed lies dormant in the ground, awaiting favourable conditions for germination. These are secured by the complete clearing of the forest growth and the burning of all refuse prior to cultivation with field crops: after the crops are reaped and the area is abandoned the teak is left in possession of the area, and the young plants establish themselves rapidly owing to the favourable light conditions and to their power of resistance to fire. Regarded purely from the point of view of association, trees which are not normally gregarious can as a rule be grown successfully in pure crops: from a silvicultural point of view, however, there are other factors to consider, among which are liability to disease or insect attacks and soil-protective capacity.

SILVICULTURAL TREATMENT. The ultimate aim of practical silviculture is the correct treatment of tree crops with the view of securing a given object; in most cases the object is to produce the highest permanent money return, involving the fullest utilization of the ground for the production of useful and valuable material. The only true basis of forest management is the detailed silvicultural study of the trees concerned, not only as individuals but also as components of communities. The vast natural forests of India, representing the greatest diversity of types and containing species exhibiting the utmost variation in silvicultural characters, present problems of a most intricate kind, the solution of which is impossible without a close study, in each case, of the oecological factors bearing on invasion, succession, and the struggle for existence. This is the more necessary in a country like India, where natural forests play a predominant part, where succession often occurs with such rapidity as to suggest a state of unstable equilibrium, and where the natural trend of

this succession may be diametrically opposed to what is desirable from an economic point of view. In this respect nothing has been more unforeseen than the effect of fire-protection in certain types of forest in moist regions, where its introduction has resulted not in the encouragement of the more valuable species, as was anticipated, but in the stimulation of progressive succession to a more hygrophilous type in which the survival of the species which it was desired to encourage above all others has been rendered impossible.

In the present work the silvicultural characters and requirements of the various species are recorded so far as observations and experiments have yielded any results. It should be noted, however, that information on such matters as light requirements, susceptibility to damage by frost, drought, grazing and other agencies, power of vegetative reproduction, and other characteristics, may be misleading if applied too generally, since information of this kind is to some extent of a comparative nature. Thus a frost-hardy species of the plains of India would succumb to cold at a high altitude, while a species regarded as drought-resistant in some localities might not be able to survive in an arid region. A shade-bearer of the deciduous forests might quickly become suppressed in dense evergreen forest. The temperate Himalayan species, though ordinarily hardy enough in their own habitat, are somewhat tender in the climate of Great Britain. It follows that some limitation is necessary in applying descriptions of silvicultural characters, and in this work such characters are ordinarily taken to apply to the natural habitat and environment of a species.

The scientific treatment, as high forest, of the large areas of irregular and for the most part mixed forests of India and Burma is one of the most difficult problems with which forest management has been faced. A provisional method of treatment, the main object of which is to utilize the available stock of mature and over-mature trees of marketable species, while endeavouring to safeguard the future stock as far as possible, was adopted in the early days of forest administration : it has continued to be the principal method of treatment down to the present day, and it must continue in force for many years to come, particularly in the less accessible tracts. This provisional treatment consists in working over the forests under a definite felling cycle and removing trees which have reached exploitable size, seed-bearers being left where natural reproduction is deficient. On the analogy of the selection system of Europe the fellings in question have been termed selection fellings, though they differ materially from those of the true selection system, under which normality is aimed at. These fellings cannot be regarded as anything but a provisional means of working the forests pending the introduction of more scientific systems of management. Their most serious defects are—first, that they do not tend towards the establishment of the normal forest ; second, that they do not ensure adequate reproduction ; and third, that in many cases they do not sufficiently take into account the silvicultural requirements of the species, particularly in the case of light-demanders. The constant removal of the more valuable species must inevitably lead to the deterioration of the forest : the felling of inferior species, it is true, is to a certain extent carried out along with the main fellings, but in too many cases it is found impossible to carry out this work

to the extent desirable, while at the best it concerns itself with the maintenance of the existing crop rather than with the building up of the future crop by inducing reproduction. Another serious defect of these selection fellings is the diffusion of work entailed by them, rendering the profitable construction of export works in many cases out of the question. There is little doubt that the adherence to these provisional selection fellings is to be explained largely on the ground of lack of sufficient knowledge of the methods necessary to secure reproduction by practicable means over the vast areas to be dealt with, and in this respect it must be admitted that in the case of the great majority of species we are as yet only on the threshold of enlightenment.

Within recent years there has been marked progress in the introduction of rational silvicultural systems in India. The defects of the selection fellings, with all the disadvantages of diffused working, are becoming more fully realized, and attention has of late been directed to the more extensive application of concentrated systems of regeneration in high forest, which until recently have been applied almost solely to pure crops of *Pinus longifolia*. Such systems aim at the complete regeneration of definite areas within given periods of time, and the eventual result will be the production of more or less even-aged, though not necessarily pure, crops in which the proportion of valuable species will be considerably higher than it is in the irregular natural crops as we find them. Some advance has already been made in the introduction of concentrated systems of regeneration in the sal forests of the United Provinces and Bengal and the teak forests of Burma, an account of which will be found under *Shorea robusta* and *Tectona grandis* respectively. The more extensive application of such systems will necessitate the close study of conditions for reproduction, and of the silvicultural characters of the species dealt with, to an extent never deemed necessary under the old system of selection fellings, and this will be not the least satisfactory result of the silvicultural revival now in progress. One striking fact which has already revealed itself is the great diversity of treatment necessary to secure reproduction under different conditions, even in the case of one and the same species, and in the application of the principle of concentrated regeneration Indian forestry will doubtless in time show a remarkable number of variations in matters of detail. The value of fire as an aid to reproduction is becoming more and more apparent, and under many conditions controlled burning will play an important part in regenerative operations, both in broad-leaved and in coniferous forest. In future artificial reproduction will almost certainly be resorted to on a much larger scale than has been the case in the past. In the moister types of sal forest in the Bengal Duars artificial reproduction is now relied on as the sole means of regenerating the sal, a species which until recently has been regarded as pre-eminently adapted for natural reproduction. Under suitable conditions natural reproduction in the teak forests of Burma can be secured with great success by clear-felling followed by thorough burning and weeding, but so far no system of natural reproduction has proved so economical and efficient as artificial reproduction with the aid of shifting cultivation. Artificial reproduction is no less a matter for local study than natural reproduction, since conditions vary to such an extent in different regions that the methods adopted must vary greatly even for one and the same species.

The next few decades should see great developments in the elaboration of scientific systems of forest management in India, leading to more economic working, more complete utilization of timber and other forest produce, the establishment of new forest industries, the extension of existing industries, and increasingly satisfactory financial returns. But in contemplating such progress let it never be forgotten that its success will depend on sound systems of forest management, which in turn must depend on strict attention to correct silvicultural details: future material progress in Indian forest development, therefore, must rest above all on the sure foundation of silvicultural research.

CONCLUSION. This work would have lost much of its value but for the generous assistance which I have received from others. I am particularly indebted to Mr. R. S. Hole, Forest Botanist, and to Mr. E. Marsden, my successor as Silviculturist at the Forest Research Institute, Dehra Dun, for much help and advice, while I am specially indebted to Mr. H. Tireman for a number of useful notes and specimens from Coorg. Numerous other forest officers have given me help in various ways, and I gladly acknowledge in particular some useful notes from the Punjab by Messrs. C. G. Trevor and R. N. Parker, notes on Bengal species by Sir Henry Farrington and Messrs. F. Trafford, J. R. P. Gent, H. S. Gibson, and E. A. C. Modder, notes from Assam by Mr. A. R. Dicks, Rai Bahadur U. N. Kanjilal, and Rai Sahib Ramnath Mukerjee, specimens from Burma prepared by Mr. J. D. Clifford with the assistance of Maung Po Thit, notes from the United Provinces by Mr. J. N. Oliphant, notes from Sind by Messrs. H. L. Newman and A. C. Robinson, notes by Mr. R. Bourne, with specimens, from Malabar, notes from Cuddapah by Messrs. T. A. Whitehead and A. Raju Nayakar, and notes from Baluchistan by Lala Mul Raj. For many of the photographic illustrations I am indebted to the kindness of others. Wherever known the photographer's name has been inserted in the list of illustrations at the beginning of each volume, but in a few cases photographs in the collection of the Forest Research Institute have been employed, of which the photographers' names could not be ascertained, and it is hoped that the omission to record them will be pardoned.

During the preparation of this work I have had frequent occasion to consult Brandis's *Indian Trees* and *Forest Flora of North-West and Central India*, Gamble's *Manual of Indian Timbers*, Talbot's *Forest Flora of Bombay*, Haines's *Forest Flora of Chota Nagpur*, Parker's *Forest Flora of the Punjab*, Kanjilal's *Forest Flora of the Siwalik and Jaunsar Forest Divisions*, Bourdillon's *Forest Trees of Travancore*, and, for species grown in the British Isles, Elwes and Henry's *Trees of Great Britain and Ireland*. Frequent reference has also been made to the pages of the *Indian Forester*. Finally I wish to acknowledge gratefully the constant assistance given me by my wife in the laborious work of preparing this book for the press.

ORDER I. DILLENACEAE

A tropical order, with one genus of some interest in Indian forestry.

DILLENIA, Linn.

Trees with large leaves on which the lateral veins are numerous, prominent, parallel, and nearly straight. After the two described below perhaps the most important are: (1) *D. aurea*, Smith, a small deciduous tree of Oudh, Chota Nagpur, on dry hills in Singhbhum, very common in places on clay schists (Haines), and the drier hill forests of Burma up to 3,000 ft.; (2) *D. pulcherrima*, Kurz, a deciduous tree occurring in *indaing* and low savannah forests in Burma.

Species 1. *D. indica*, Linn.; 2. *D. pentagyna*, Roxb.

1. *Dillenia indica*, Linn. Syn. *D. speciosa*, Thunb. Vern. *Chalta*, Hind., Beng.; *Uva*, Tam., Tel.; *Mota karmal*, Mar.; *Thabyu*, Burm.

An evergreen tree attaining a height of 30–40 ft., or more in favourable localities, with spreading branches and a rounded crown with handsome bright green shady foliage. Bark smooth, red, moderately thick, exfoliating in small hard scales.

DISTRIBUTION AND HABITAT. Moist and evergreen forests of the eastern sub-Himalayan tract, Assam and Burma, and the moister parts of the Indian Peninsula. Often planted for ornament. Characteristically found along the banks of tropical forest streams and other damp places, on deep rich moist soil. In its natural habitat the tree is found in regions with an absolute maximum shade temperature of 95°–105° F., an absolute minimum of 35°–65° F., and a rainfall of 80 to 200 in. or more.

LEAF-SHEDDING, FLOWERING, AND FRUITING. In Dehra Dun the tree is almost leafless for a brief period in July. The large handsome white flowers appear in June and July, or in August at Dehra Dun; the petals quickly fall. The green fruits (Fig. 1, *a, b*), resembling large apples, commence to ripen in October, and continue to fall to the ground throughout the following cold and hot seasons. The fruit is a pseudocarp 3–5 in. in diameter, consisting of the much-thickened sepals enclosing a ring of fleshy carpels in which the seeds are embedded in a glutinous mass of pulp. The seeds (Fig. 1, *d*) are compressed, reniform, dark brown, with hairy margins, when dry measuring about 0.25 in. by 0.15 in.; 1,100–1,500 seeds weigh 1 oz.

The fruits are buoyant in water, and those which drop into the streams from the trees along their banks are carried down until stranded. Wild elephants eat the fruits, and are a possible cause of the spread of the seed. Under ordinary conditions, however, the seed has no means of escaping from the fruit owing to the stiff tight covering of thickened sepals, and Nature's method of overcoming the difficulty is interesting. The fruits on reaching the ground quickly turn brown, decay, and in the hot season shrivel into dry masses; at the same time white ants eat out the interior and fill the dry

shell with their earth. The seeds, however, remain untouched, and at the commencement of the rains they germinate in the earth of the white ants, and seedlings burst out through all the cracks and joints of the dried shell of the fruit as if growing in a flower-pot (Fig. 1, c). The heavy rain soon breaks up the remnants of the fruit and washes away the seedlings, the roots of which obtain a footing wherever they can; many seedlings, however, die before this is accomplished. Where the fruits have become partially buried and the seedlings remain *in situ* they succeed best.

GERMINATION (Fig. 1, e-g). Epigeous. In the case of detached seeds the testa, enclosing the cotyledons, is usually carried up, dropping with the expansion of the cotyledons. When, as under natural conditions, germination takes place within the shell of the fruit, the hypocotyl often becomes much curved in its efforts to emerge, and the testa is frequently left inside.

THE SEEDLING (Fig. 1).

Roots : primary root long, tapering, wiry, flexuose : lateral roots numerous, moderately long, fibrous. **Hypocotyl** distinct from root, 1.7-2.5 in. long, terete, fusiform or tapering slightly upwards, glabrous, often much bent and curved during germination. **Cotyledons** sub-sessile or with very short petioles, green, foliaceous, 0.6-0.8 by 0.3-0.4 in., ovate, acute or acuminate, base acute, entire, glabrous. **Stem** erect, more or less covered by the expanded petiole bases. **Leaves** alternate, crowded : petiole 0.1-0.3 in., somewhat enlarged at the base and partly sheathing the stem : lamina 0.5-2 by 0.4-0.8 in., elliptical obovate, sharply serrate, glabrous above, pubescent beneath, lateral veins parallel, prominent.

In the second season the seedling develops considerably, the stem thickening and the leaves acquiring more the character of those of the adult plant. At Dehra Dun nursery plants reached a height of 6 to 10 in., 2 to 3½ ft., and 5 to 6 ft. by the end of the second, third, and fourth seasons respectively. Seedlings suffer from drought in dry weather, and require regular watering in the nursery. Where raised in localities subject to frost the seedlings are decidedly tender, and require protection.

SILVICULTURAL CHARACTERS. The tree is a shade-bearer, vigorous saplings being found in the forest under dense shade. It thrives best in damp situations on deep fertile soil. In the abnormal frost of 1905 trees in gardens in the Punjab and United Provinces suffered severely. The tree reproduces satisfactorily from coppice-shoots, as in the Holongapar coppice coupes, Assam.

ARTIFICIAL REPRODUCTION. Many attempts have been made at Dehra Dun to ascertain the best methods of propagating the tree by seed. Failure resulted in every case where the seed was extracted from green or rotten (not dry) fruits. Two methods proved successful :

(1) To collect the fruits about December to February and dry them thoroughly in the sun for a few months, then to hammer them open and extract the seeds by winnowing; then to sow the seeds about May in boxes or nursery beds and water them regularly.

(2) To place the fruits on the ground and leave them till the commencement of the rains, when the seeds germinate inside as already described; the seedlings obtained thereby are then removed and planted in nursery beds.

Transplanting can best be done at the commencement of the first rains after sowing, when the plants are one year old; they are then usually 3-4 in.



FIG. 1. *Dillenia indica* SEEDLING

a -Fruit $\times \frac{1}{4}$ b -Fruit in cross section $\times \frac{1}{4}$ c Seedlings germinating inside decayed fruit $\times \frac{1}{4}$
 d Seed $\times \frac{1}{2}$ e g Germination stages $\times \frac{1}{2}$ h - j--Development of seedling during first season $\times \frac{1}{2}$
 k- Seedling early in second season $\times \frac{1}{2}$

high. Even in the second or third year after sowing the plants can be transplanted without much risk if care be taken to keep earth round the roots.

RATE OF GROWTH. The tree grows moderately fast. Gamble's measurements gave 7 and 9 rings per inch of radius for two specimens, corresponding to a mean annual girth increment of 0.9 in. and 0.7 in.

2. *Dillenia pentagyna*, Roxb. Syn. *D. augusta* and *D. pilosa*, Roxb. Vern. *Aggai*, Oudh; *Kallai*, C.P.; *Aksi*, Duars, Assam; *Karmal*, Mar.; *Kangal*, Kan.; *Nai teku*, Tam.; *Zinbyun*, Burm. (Fig. 2.)

A deciduous tree attaining in favourable localities a height of 60–70 ft. and a girth of over 8 ft., with a rounded crown and very large leaves, those of young saplings and coppice-shoots sometimes as much as 3 ft. in length. Bark greyish brown, moderately thick, smooth, with shallow depressions.

DISTRIBUTION AND HABITAT. Sub-Himalayan tract from Oudh eastwards, Bengal, Chota Nagpur, Assam, Burma, central, western, and southern India. In Oudh the tree occurs mainly in sal forests and does not attain very large dimensions. In Bengal and Assam it is characteristic of savannah lands and is common in sal forest. In Chota Nagpur it is not very common, and is confined mainly to low ground, but according to Haines it ascends to 2,000 ft. on Parasnath. In Burma it is a very common tree in certain types of lower mixed deciduous forest on alluvial ground, where sometimes it becomes almost gregarious: it also extends into the upper mixed forest. Talbot says that it occurs throughout the Bombay Presidency in deciduous monsoon forests, that it is usually found stunted and of medium size in the dry open forests of Guzerat, Khandesh, and other Deccan districts, and also occurs in the mixed forests of North Kanara, where it attains considerable dimensions.

In its natural habitat it is found in regions with an absolute maximum shade temperature of 96°–115° F., an absolute minimum of 32°–60° F., and a normal rainfall of 30–180 in. or more; where the rainfall is less than 45 in., however, the tree is usually stunted.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The leaves turn brown and fall in February, sometimes even in January, and the trees remain leafless for two or three months. The flower-buds appear in January on excrescences along the thick twigs, and even down to fair-sized branches, and the numerous fragrant yellow flowers in fascicles along the leafless branches appear in March–April. The fruits ripen about May–June; they are orange yellow in colour, succulent, edible, about $\frac{1}{2}$ – $\frac{3}{4}$ in. in diameter, and fall to the ground soon after ripening. They are greedily eaten by birds. Seeds about 0.2 in. by 0.1 in., rounded or angular, dark brown, smooth, shining; testa hard, but not difficult to break. About 1,300 seeds weigh 1 oz.

SILVICULTURAL CHARACTERS. The tree is a light-demander. It is very sensitive to frost, but stands fire well. Its coppicing power varies, though as a rule it is good: in three plots in coppice coupes 1 and 2 years old in the Tikri forest, Gonda, measured in 1911, *Dillenia* stools had an average of 1.6, 2.4, and 2.6 shoots per stool as against 1.8, 1.7, and 2.2 respectively for sal. Measurements by Mr. C. M. McCrie in 1910 at Ramgarh, Gorakhpur, United Provinces, in coppice coupes 5, 7, and 16 years old, showed an average of 1, 1.75, and 1 shoot per stool as against 1.28, 1.34, and 1.5 respectively for sal. In the Bengal Duars and the plains forests of Burma the tree produces strong

stool-shoots in the coppice coupes. On the other hand, Mr. A. E. Osmaston¹ records that of 12 *Dillenia* trees coppiced in a plot in Gorakhpur none produced shoots: these forests suffered severely from drought shortly before the fellings were made, and this may account for the failure.

NATURAL REPRODUCTION. The tree reproduces freely in burnt savannahs, often forming pure patches: the thick almost fleshy shoots of saplings stand burning to a remarkable degree. In the Duars the presence of *Dillenia pentagyna* in sal or mixed forest thus often denotes that the crop has grown up within comparatively recent times out of burnt savannah land.

RATE OF GROWTH. Periodical measurements of *Dillenia* trees in sample plots in sal forest in the Buxa Division, Bengal, showed such slow growth (a mean annual girth increment of 0.25 in.), owing to the fact that the trees were dominated by the sal, that the figures were discarded as unreliable: they are, however, interesting as showing the light-demanding nature of the tree. Gamble's specimens showed 5 to 6 rings per inch of radius, representing a mean annual girth increment of 1.1 in., a fairly rapid rate of growth.

In the Gonda coppice plots referred to above *Dillenia* stool-shoots 1 and 2 years old had average heights of 2.6 ft. and 5.8 ft. respectively as against 4.7 and 8.8 ft. for sal shoots. Measurements in the Gorakhpur coppice plots already mentioned gave the following results in the case of *Dillenia* as compared with sal:

Dillenia pentagyna: rate of growth of coppice, Gorakhpur.

Age. years.	Mean height.		Mean girth.	
	<i>Dillenia pentagyna.</i> ft.	<i>Shorea robusta.</i> ft.	<i>Dillenia pentagyna.</i> in.	<i>Shorea robusta.</i> in.
2	4.0	3.0	2.0	—
4	7.1	7.0	3.6	2.0
6	9.3	10.3	4.8	2.9
8	11.1	13.0	5.4	3.8
10	12.3	15.3	5.8	4.8
12	13.3	17.5	6.1	5.8
14	13.8	19.2	6.4	6.7
16	14.1	20.9	6.6	7.5

ORDER II. MAGNOLIACEAE

This order, which has most of its representatives in the moist forests of the eastern Himalaya and Assam, contains several trees of great beauty and some of large size.

MICHELIA, Linn.

Large evergreen or deciduous trees of the moist or evergreen forests, chiefly in hilly regions. Besides the two described below, *M. nilagirica*, Zenk., of the evergreen 'sholas' of the Nilgiris, and *M. oblonga*, Wall., a very large tree of Assam, are of some importance in their respective regions.

Species 1. *M. excelsa*, Blume; 2. *M. Champaca*, Linn.

1. *Michelia excelsa*, Blume. Vern. *Bara champ*, *safed champ*, Nep.

A tall deciduous tree usually with a straight clean bole and a compact

¹ Ind. Forester, xxxvii (1911), p. 429.

or only moderately spreading crown. Bark of young trees whitish, that of old trees light ashy grey with numerous small pits. Mature trees attain a height of 100–120 ft., while sound trees up to 10 ft. in girth are not infrequently found: trees of larger girth are usually unsound. A tree 22 ft. in girth has been reported by Mr. J. R. P. Gent in the Singalila range, Darjeeling. Fig. 3 shows a large tree with its branches characteristically festooned with moss. This is one of the most important timber trees of the Darjeeling hills, where the wood is in great demand for building and other purposes. It furnishes a poor fuel.

DISTRIBUTION AND HABITAT. Eastern Himalaya at 5,000–8,000 ft., Khasi and Naga hills. In the Darjeeling forests it occurs mixed with oaks (*Quercus lamellosa*, *Q. lineata*, and *Q. pachyphylla*), *Castanopsis Hystrix*, *Bucklandia populnea*, maples, laurels, and other trees. It grows on well-drained hill-sides or ridges, preferring the lighter moist deep loamy soils; it also grows fairly well when planted on moderately clayey soil, but bad drainage and excessive soil moisture are injurious, retarding the development of the tree and producing a stunted growth. Fig. 4 shows a pole crop normally developed, and Fig. 5 a pole crop somewhat stunted owing to an excess of moisture in the soil.

In the natural habitat of the tree the climate is temperate and very wet. The absolute maximum shade temperature varies from 80° to 90° F., the absolute minimum from 20° to 30° F., and the normal rainfall from 90 to 200 in. or more.

FLOWERING AND FRUITING. The majority of the trees flower in March, but sometimes trees may be found flowering in December and occasionally at other times of the year: the flowers are large and white. The seed ripens towards the end of October and in November, and is distributed to some extent by the agency of birds, though much of it germinates where it falls. The seeds, which are covered with a red arillus, are oily and quickly lose their germinative power: about 160 to 210 weigh 1 oz. They are readily devoured by birds and by squirrels, rats, and other vermin. Records of seed-years for some time past show that in 11 years there are on an average 5 good, 3 moderate, and 3 bad seed-years. Hailstorms, which occur mainly in March and April, destroy the flowers or the young fruits before they set, sometimes causing complete failure to produce seed in an otherwise promising seed-year.

SILVICULTURAL CHARACTERS. The tree is a light-demander. Although seedlings grow fairly well under a moderate though high canopy, saplings and poles grown with complete overhead light are more vigorous than those grown under shade. Sudden isolation, as when standards are left in coppice coupes, is apt to cause drying of the crown and the production of numerous epicormic branches: this is probably the result, in part at least, of the altered conditions of soil moisture consequent on the exposure of the ground. The tree coppices well up to a fair size: it does not produce root-suckers. Drought does not ordinarily occur in its natural region, but young plants on southerly aspects are sometimes found to suffer from want of moisture. The tree is frost-hardy. It suffers much if exposed to fire, trees being often killed outright where fires are severe: young trees, however, frequently send up new shoots from the base. It is more subject to the attacks of animals than almost any other tree of its region. Squirrels and tree shrews gnaw the bark near the ground and

eat the tips of young shoots: young plants in particular are subject to the attacks of squirrels. The bark is also eaten by cattle and deer, while the tree is a favourite one for deer to rub their antlers on. The leaves and young plants are readily eaten by cattle, horses, and deer, and in grazed areas it is impossible for the seedlings to establish themselves.

NATURAL REPRODUCTION. Good seed-years produce an abundant crop of seed, and seedlings of the first year are usually plentiful in the vicinity of seed-bearers. Their further development depends largely on the admission of sufficient light and on their being kept free from suppression by weeds and from damage by fire and grazing. Natural reproduction is found most plentifully on ridges and spurs, the reason probably being that on such places there is more light, less accumulation of fallen leaves, and a less abundant growth of weeds than elsewhere. In the Darjeeling forests natural reproduction is induced by opening the canopy in the vicinity of seed-bearers: wounding the soil has also given success.

ARTIFICIAL REPRODUCTION. In the Darjeeling hills artificial reproduction is carried out to a considerable extent by means of transplanting nursery-raised seedlings. The fruits are collected early in November, and spread out in the sun until the seeds separate from the husks, this taking from a week to a month according to the weather. The seed is then sown within a week, having been kept spread out meanwhile in an airy place under light shade. In the nursery it is sown either in drills or broadcast, the latter method being considered preferable owing to the danger of moles, which find the seed in lines and following up a line devour every seed. When 1 to 2 in. high the seedlings are pricked out 6 in. apart in nursery beds during the first rainy season, but this is sometimes dispensed with.

The seedlings are transplanted to the forest when 3 or 4 years old and 2 to 3 ft. high, the latter size being considered preferable in order to give the plants a better start over the weed-growth. Transplanting is usually carried out in the rainy season, about July, but if the winter rains are favourable it can be carried out successfully in January, especially on northerly slopes. As a rule a spacing of 10 ft. by 10 ft. is considered sufficient; inferior species spring up in the intervening spaces, producing a full crop, and are afterwards cut out, leaving a pure crop of *Michelia*. Careful fencing against deer is necessary. In the Darjeeling hills it is customary to fence every plant until it is out of reach of deer by driving a circle of split stakes round it. For three years cleaning is necessary twice a year, during and towards the end of the rainy season, in order to prevent suppression of the young plants by weeds.

RATE OF GROWTH. According to Gamble the rate of growth is variable, young trees often showing only 4 to 7 rings per inch of radius, older ones 12 to 16; this gives a mean annual girth increment of 0.39 to 0.52 in. A specimen in the Darjeeling Forest Museum, with a girth of 7 ft. 7 in., showed 7 rings per inch of mean radial growth, giving a mean annual girth increment of 0.9 in. Ring countings by Mr. F. G. Henvey, recorded in the Darjeeling working plan, showed 8 to 12 rings per inch of radius, giving a mean annual girth increment of 0.52 in. to 0.78 in. More recent results of ring countings have shown an average of 9 rings per inch of radius, giving a mean annual



FIG. 2. *Dillenia pentagyna*, girth 8 ft. 6 in., Buxa district, Bengal.



FIG. 3. *Michelia excelsa*, girth 9 ft. 3 in., height about 110 ft., clear bole about 75 ft., Hills.

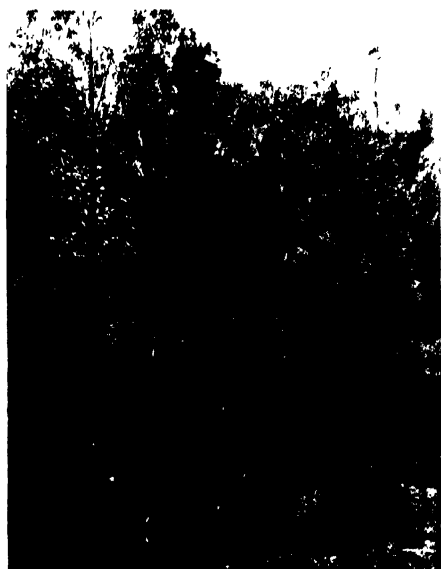


FIG. 4. *Michelia excelsa*, pole crop about 20 years old, normally developed, Darjeeling Hills.

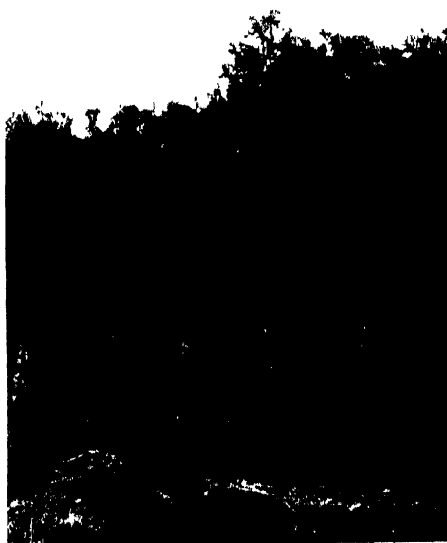


FIG. 5. *Michelia excelsa*, pole crop about 20 years old, stunted owing to excess of moisture in the soil, Darjeeling Hills; trees in flower.

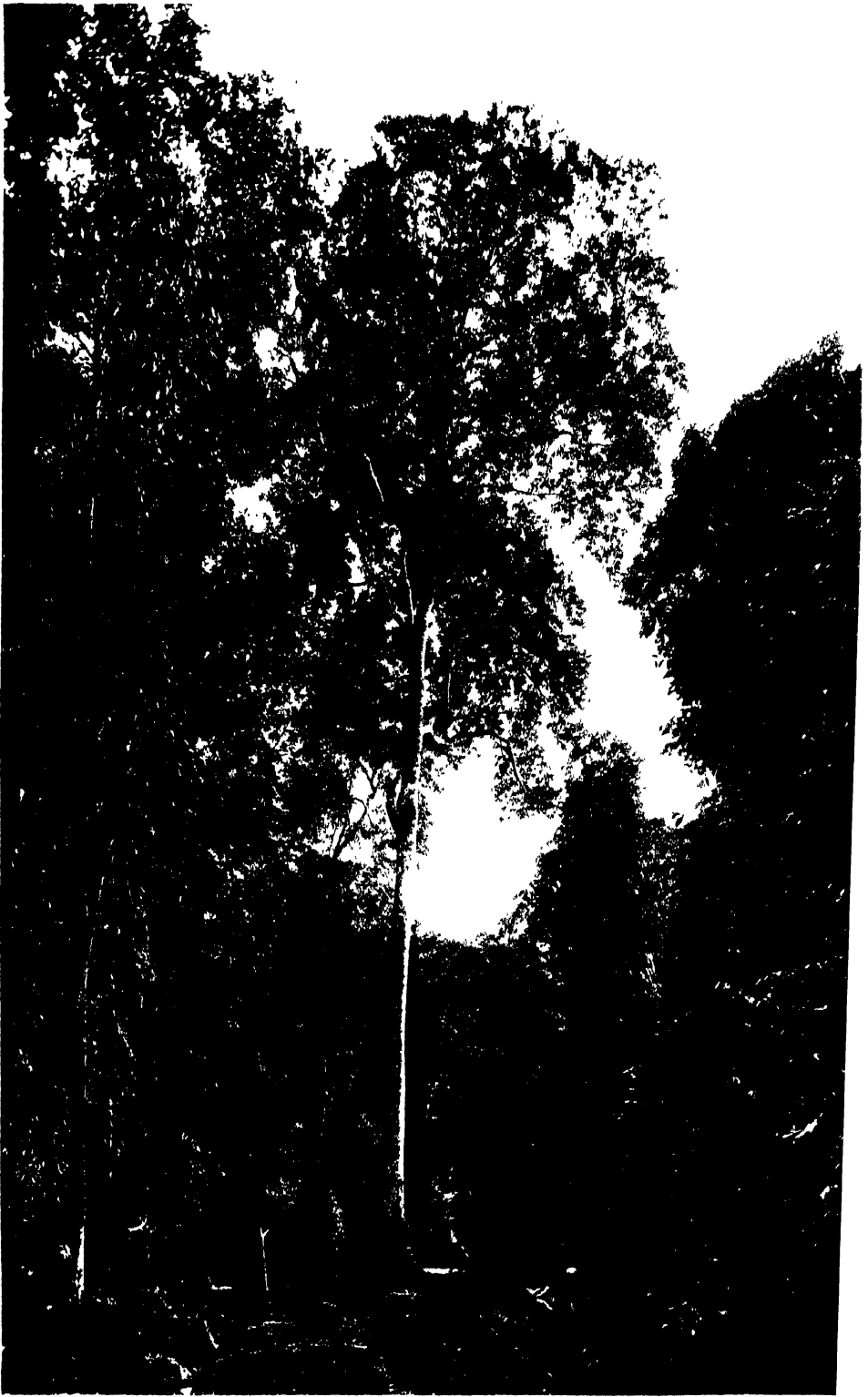


FIG. 6. *Michelia Champaca* in evergreen forest, Bengal Duars, girth 8 ft. 9 in., height 110

girth increment of 0.7 in., which may be taken as an approximate general average.

Mr. H. S. Gibson has furnished the following figures showing the average height of seedlings and saplings in the Kurseong forests :

Michelia excelsa : growth of seedlings and saplings, Kurseong forests.

Age. Years.	Height.		Girth.	
	Natural. ft. in.	Artificial. ft. in.	Natural. ft. in.	Artificial. ft. in.
1 . . .	0 7	0 9		
2 . . .	1 0	1 6		
3 . . .	2 0	2 6		
4 . . .	3 0	3 0		
5 . . .	5 0	3 6		
6 . . .	7 6	4 6		
7 . . .	10 0	5 6		
10 . . .	14 0	8 0		
15 . . .	22 0	14 0		
20 . . .	30 0	22 0	1 6	0 10
25 . . .		35 0		1 6

A plot of young trees in an abandoned nursery at Rangirum in the Darjeeling hills, measured in 1917, had a mean girth of 9.2 in. and a mean height of 27 ft. ; it had 1,376 stems per acre and a volume of 687 cubic ft.

The average rate of growth of coppice-shoots is from 2 to 3 ft. annually.

2. *Michelia Champaca*, Linn. Syn. *M. aurantiaca*, Wall. Champak. Vern. *Champ*, *champa*, Hind. ; *Tita sopa*, Ass. ; *Sampighi*, Kan. ; *Champakam*, Tel. ; *Shembuga*, Tam. ; *Saga*, Burm.

A tall handsome evergreen tree with a long clean cylindrical bole, attaining a height of 110 ft. or more and under ordinary forest conditions a girth of 8–12 ft. or more. Bark light grey, smooth, about $\frac{1}{2}$ in. thick. In the Borojhar forest, Buxa Duars, I measured a tree 16 ft. in girth, while Beddome records a tree on the Balarangam hills in Mysore with a girth of over 50 ft.

DISTRIBUTION AND HABITAT. Wild in the eastern sub-Himalayan tract and lower hills up to 3,000 ft., Assam, Burma, Western Ghats, southern India. Rare in deep valleys cooled by perennial springs, in the Tholokabad and Karampoda forests, Chota Nagpur (Haines). Much cultivated in various parts of India and Burma, especially round temples, for the sake of its fragrant flowers, which are used in religious ceremonies. It is characteristic of moist and evergreen forests, where its tall clean light grey bole stands out conspicuously (see Fig. 6). In the Bengal Duars it is fairly common in the moister and almost evergreen types of sal forest on rich soil. Some fine specimens occur along the foot-hills of this tract. It extends into the Abor country at the lower elevations, and Mr. A. J. Milroy¹ remarks on the large size of the trees he saw there, the best of which measured 10 ft. in girth with a clean cylindrical bole of about 70 ft. : he was informed that the tree grows to still finer proportions in the Mishmi and Khamti countries.

In its natural habitat the tree is ordinarily found in regions where the absolute maximum shade temperature varies from 95° to 105° F., the absolute minimum from 38° to 62° F., and the normal rainfall from 90 to 200 in. or more.

¹ Report on the Forest Resources of the Abor Country, 1912.

FLOWERING AND FRUITING. The scented yellow flowers appear in the hot season and the rainy season, and the fruit ripens about August or later. The seeds are dark brown and angular, and are covered with a pink fleshy arillus : about 160 to 300 seeds weigh 1 oz. They are oily and quickly lose their germinative power. Seed-year records from the Kurseong and Tista divisions, Bengal, show that a good seeding may be expected nearly every year.

SILVICULTURAL CHARACTERS. The tree is a moderate light-demander. It thrives best in a damp climate, and requires a moist deep soil.

ARTIFICIAL REPRODUCTION. The seeds should be sown as soon after collection as possible : the seedlings may be transplanted from the nursery in the second year after sowing.

RATE OF GROWTH. Gamble's specimens showed 6 to 7 rings per inch of radius, giving a mean annual girth increment of about 1 in., which is a fair rate of growth.

ORDER III. ANONACEAE

From a forest point of view this order is not of great importance.

Genera 1. *MILIUSA*, Lesch.; 2. *SACCOFETALUM*, Bennett; 3. *CANANGIUM*, Baill.; 4. *POLYALTHIA*, Blume.

1. *MILIUSA*, Leschenault.

Miliusa velutina, Hook. f. and Th. Syn. *Uvaria villosa*, Roxb. Vern. *Dom-sál*, Hind.; *Barhi*, *kári*, Oudh, C. P.; *Omé*, Singhbhum; *Thabut-gyi*, Burm.

A moderate-sized, in Burma a fairly large, deciduous tree with a somewhat short trunk, spreading branches, a comparatively large crown, and large soft leaves with an aromatic smell when crushed. Bark dark grey, longitudinally fissured.

DISTRIBUTION AND HABITAT. Sub-Himalayan tract from the Jumna eastwards, Oudh, Chota Nagpur, Orissa, Central Provinces, Northern Circars, and Burma. In Burma it is found scattered in mixed deciduous forests over a considerable portion of the province, being commoner in the lower mixed than in the upper mixed types. In India it is a characteristic tree in many sal forests, and is also found in open mixed deciduous forests. In its natural habitat the absolute maximum shade temperature varies from 105° to 115° F., the absolute minimum from 30° to 55° F., and the normal rainfall from 40 to 90 in.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The tree is leafless about February–March, the new leaves appearing in March–May, and the pale yellow flowers with them; the fruit ripens in June–July.

SILVICULTURAL CHARACTERS. In sal forests the utility of the tree lies chiefly in its capacity for regenerating in small blanks containing coarse grasses, where it forms a natural nurse for the regeneration of the sal. Although somewhat frost-tender, it is conspicuously hardy against drought, as was proved in the abnormal drought of 1907–8 which devastated the sal forests of Oudh : for this reason it has been of special value as an accessory species in these forests. The tree is a moderate shade-bearer. It coppices well, and also reproduces from root-suckers. Mr. A. E. Osmaston records that in coppice experiments

in Gorakhpur, United Provinces, of 22 trees coppiced every one sent up stool-shoots. Countings which I made in 1911 in the Tikri forest, Gonda, United Provinces, showed an average of 2.1 shoots per stool for 21 stools in one-year-old coppice as against 2.2 shoots for sal, and 1.4 shoots per stool for 12 stools in two-years-old coppice as against 1.7 shoots for sal. In the Ramgarh coppice coupes, Gorakhpur, in 1910 Mr. C. M. McCrie found in coupes 3, 5, 11, 15, and 16 years old 2, 1.33, 1, 1.16, and 1.15 shoots per stool respectively.

RATE OF GROWTH. Figures in existing sample plots show a comparatively slow rate of growth in girth; trees between 1½ and 3 ft. in girth in sample plots in the Lansdowne and Gonda divisions of the United Provinces showed mean annual girth increments of 0.19 in. and 0.15 in. respectively. The rate of growth of coppice-shoots is slower than in the case of sal. In the Gorakhpur experiments referred to above the average height of stool-shoots of one rainy season's growth was 2.1 ft. as against 4.5 ft. for sal. In the Gonda coppice coupes already mentioned coppice-shoots one year old had an average and maximum height of 5 and 8 ft. respectively as against 4.7 and 11 ft. for sal, while in two-years-old coupes *Miliusa* shoots had an average height of 6.5 ft. as against 8.6 ft. for sal. Measurements made by Mr. C. M. McCrie in 1910 in coppice coupes of various ages in the Ramgarh forest, Gorakhpur, showed the following rate of growth of coppice-shoots of *Miliusa* as compared with sal:

Miliusa velutina : rate of growth of coppice, Gorakhpur.

Age. Years.	Mean height.		Mean girth.	
	<i>Miliusa velutina</i> . ft.	<i>Shorea robusta</i> . ft.	<i>Miliusa velutina</i> . in.	<i>Shorea robusta</i> . in.
2	5.4	3.0	1.2	—
4	8.2	7.0	1.9	2.0
6	10.0	10.3	2.6	2.9
8	11.6	13.0	3.3	3.8
10	13.1	15.3	3.6	4.8
12	13.9	17.5	4.0	5.8
14	14.6	19.2	4.3	6.7
16	15.1	20.9	4.5	7.5

2. SACCOPETALUM, Bennett.

Saccopetalum tomentosum, Hook. f. and Th. Vern. *Kari, um, umbi*, Hind. ; *Gonda, Uriya* ; *Chilkadudu*, Tel.

A moderate-sized to large deciduous tree of the Nepal *tarai*, Oudh, Chota Nagpur, and the Indian Peninsula. It is of little economic importance, but is fairly widely distributed, and in Oudh is one of the companions of the sal. It coppices well, the rate of growth of the shoots being somewhat less than that of sal coppice: Mr. A. E. Osmaston records that of 7 trees coppiced in experimental coupes in Gorakhpur, 6 produced shoots with an average height of 3.3 ft. in one rainy season as compared with 4.5 ft. for sal.

3. CANANGIUM, Baillon.

Canangium odoratum, Baill. Syn. *Cananga odorata*, Hook. f. and Th. Vern. *Kadatanan*, Burm.

A very large fast-growing evergreen tree, wild in Tenasserim and often

cultivated in different localities for its scented flowers. It may attain a height of 120 ft. or more and has a long clear bole sometimes nearly 100 ft. high. The tree flourishes in damp localities. The seeds are small, 500–600 weighing 1 oz.

4. POLYALTHIA, Blume.

Species 1. *P. cerasoides*, Benth. and Hook. f.; 2. *P. longifolia*, Benth. and Hook. f.; 3. *P. fragrans*, Benth. and Hook. f.

1. *Polyalthia cerasoides*, Benth. and Hook. f. Vern. *Guthi*, Tel.; *Thabuthein*, Burm.

A small to moderate-sized tree of Bihar, Chota Nagpur, in valley forests and along ravines (Haines), the Indian Peninsula, usually on dry hills but sometimes in evergreen forest, and Burma, often in *indaing* forest. Mr. J. Donald notes that there is a high percentage of regeneration of this tree as a result of fire-protection in parts of South Chanda. The tree possesses the power of reproduction by root-suckers.

2. *Polyalthia longifolia*, Benth. and Hook. f. Vern. *Asok*, Hind.

A handsome evergreen tree with a round close crown, indigenous in Ceylon and much cultivated in gardens and avenues in India and Burma. Its growth is slow. The seeds, which ripen in July and August, do not keep their germinative power long, and require to be sown as soon as possible after ripening. The young plants do not stand transplanting well, and to ensure the best results the seed should be sown at site or in baskets.

3. *Polyalthia fragrans*, Benth. and Hook. f.

'A tall, evergreen, buttressed tree, 80 ft. high by 2 ft. in diameter, with smooth grey bark. . . . Endemic in the Western Ghats, evergreen tropical rain-forests of the Konkan and North Kanara, often gregarious' (Talbot). The timber is of little value.

ORDER IV. CAPPARIDACEAE

The chief silvicultural importance of this order lies in the fact that some of its members, particularly species of *Capparis* and *Cadaba*, occur in dry or arid tracts where vegetation of any kind is scanty.

Genera 1. CRATAEVA, Linn.; 2. CAPPARIS, Linn.

1. CRATAEVA, Linn.

Crataeva religiosa, Forst. Syn. *C. Nurvala*, Ham.; *C. Roxburghii*, R. Br. Vern. *Bárna*, *viliana*, Hind.; *Nirvala*, Mar.; *Maralingam*, Tam.; *Bitusi*, Kan.; *Kadet*, *kadet*, Burm.

A moderate-sized deciduous tree with long-petioled trifoliate leaves; bark grey, somewhat smooth, with horizontal wrinkles. The soft whitish even-grained wood is used for drums, writing-boards, &c., and in turnery.

DISTRIBUTION AND HABITAT. Throughout most parts of India and Burma, wild or cultivated. It is often found along streams, but sometimes occurs almost gregariously on dry deep boulder formations in the sub-Himalayan tract, for example near Ramnagar.



FIG. 7. *Crataeva religiosa*- SEEDLING $\times \frac{1}{4}$

a - Seed b - e - Germination stages f - h - Development of seedling during first season
(In Fig h only $\frac{1}{4}$ length of taproot is shown)

LEAF-SHEDDING, FLOWERING, AND FRUITING. The tree is leafless in the cold season, the new leaves appearing in February and March. The handsome lax-clustered flowers, white turning yellowish or pale pink, having numerous prominent stamens with purple filaments, appear in March-May (December-April in southern India?), and the fruit, a hard-rinded many-seeded berry, 1-2 in. in diameter, ripens in the rains (about August in northern India). The seeds (Fig. 7, *a*) are about 0.2 in. in diameter, somewhat compressed, helicoid-reniform or irregularly circular, dark brown; testa hard but splitting readily along a suture round the seed. About 600-700 seeds weigh 1 oz. Tests at Dehra Dun showed that the fertility of the seed is not high, and that germinative power is retained to some extent for at least ten months.

GERMINATION (Fig. 7, *b-e*). Epigeous. The testa splits, enabling the radicle to emerge. The hypocotyl elongates by arching, and in straightening elevates the cotyledons above ground. The testa clings for some time to the ends of the cotyledons, falling to the ground as they expand.

THE SEEDLING (Fig. 7).

Roots: primary root very long, often becoming 15 in. or more in length in the first season, moderately thick, terete, flexuose; lateral roots fibrous, somewhat fine. *Hypocotyl* distinct from root, 0.8-2 in. long, terete, fusiform or tapering upwards, white at first, soon turning green, glabrous. *Cotyledons* sub-sessile or with petioles 0.1 in. or less, flattened above: lamina 0.6-1.1 in. by 0.1-0.2 in., foliaceous, somewhat fleshy, ligulate, apex and base acute or rounded, entire, green, glabrous, persisting for the greater part of the first growing season. *Stem* erect, terete, glabrous, grey with young parts green; internodes 0.2-0.4 in. long. *Leaves*, first pair usually opposite, subsequent leaves alternate, normally trifoliate but in first pair leaflets often connate, early leaves small, later ones increasing in size. Stipules absent. Petiole 0.4-1.8 in. long, glabrous, channelled above. Leaflets on short petiolules, entire, glabrous, sub-coriaceous, central leaflet 0.6-4.2 in. by 0.4-1.8 in., ovate or obovate lanceolate, acuminate, lateral leaflets 0.5-3 in. by 0.3-1.5 in., obliquely ovate, acuminate or acute.

SILVICULTURAL CHARACTERS. Although often found in moist shady places the tree is more a light-demander than a shade-bearer. It is partial to loose deep alluvial soil near streams, while its long taproot enables it to grow on deep boulder formations where water is at some depth. It is sensitive to frost, at all events in its early stages. It produces root-suckers freely.

NATURAL REPRODUCTION. Experiments carried out at Dehra Dun showed that two conditions favourable for natural reproduction are bare ground and sufficient moisture. Seed scattered in grass or among weeds both on moist and on dry ground, or in dry situations on bare soil, persistently failed to germinate, while if scattered on moist bare ground it germinated both in the open and under dense shade, though in the latter case the shade soon killed off the seedlings.

ARTIFICIAL REPRODUCTION. Seed should be sown at the time of ripening, in the rains, on deep loose soil kept sufficiently watered, or in deep pots or boxes, and transplanted during the following rains. The seed may not germinate, even if kept regularly watered, until about May or June of the year after sowing, in which case the plants will be ready for transplanting about August or early September; they are then ordinarily about 3-6 in. high. Owing to the long taproot care is necessary in transplanting.

2. CAPPARIS, Linn.

Capparis aphylla, Roth. Vern. *Karil*, Punjab.

A much-branched shrub or small tree of the open dry scrub forests in the Punjab, Sind, Rajputana, Baluchistan, Guzerat, and the drier parts of the Peninsula. In these dry tracts it is associated with *Prosopis spicigera*, *Acacia leucophloea*, *Salvadora oleoides*, and other semi-desert species. With *Prosopis* and *Salvadora* it forms the bulk of the vegetation of the dry *rakhs* of the Punjab plains. Talbot says it is common on alluvium along the banks of the Deccan rivers mixed with *Acacia arabica* and *Zizyphus Jujuba*. It coppices well and produces root-suckers freely. It has a mass of slender thorny green leafless branches, the small caducous leaves being found only on the young shoots. The new shoots appear in the cold season. The tree is a conspicuous sight when covered with red flowers in the early part of the hot weather, about March and April. The round pink fleshy fruit is eaten by birds.

ORDER V. BIXACEAE

This order is not of great silvicultural importance ; it contains, however, one tree, *Taraktogenos Kurzii*, King, likely to become of considerable value owing to the oil yielded by its seeds, which is used in the treatment of leprosy.

Genera 1. COCHLOSPERMUM, Kunth ; 2. FLACOURTIA, Commers. ; 3. HYDNO-CARPUS, Gaertner ; 4. TARAKTOGENOS, Hassk.

1. COCHLOSPERMUM, Kunth.

Cochlospermum Gossypium, DC. Syn. *Bombax Gossypium*, Roxb. Vern. *Kumbi*, *gabdi*, *gejra*, Hind. ; *Ganglay*, *galgal*, Mar. ; *Gungu*, *kong*, Tel. ; *Kongillam*, Tam. ; *Buruga*, Kan.

A small deciduous tree with palmately lobed leaves and fibrous deeply furrowed bark, occurring in the western sub-Himalayan tract from the Sutlej eastwards, ascending to 3,000 ft., Chota Nagpur, Bundelkhand, the drier parts of the Indian Peninsula, and the dry region of Burma. The tree is characteristic of dry hilly country, occupying the hottest and stoniest slopes. Talbot says it is one of the few species capable of resisting successfully the fierce annual forest fires of the Khandesh Deccan Satpuras. In the abnormal drought of 1899 and 1900 in the Deccan it was only slightly affected. It is a light-demander, coming up in open forests exposed to full sunlight. The tree is leafless from about November or December to May, and the large bright yellow flowers appear at the ends of the leafless branches in February and March ; it is then a conspicuous sight. The fruit, a large capsule, ripens in May and June, the seeds being carried long distances by the strong winds which are often prevalent before or at the commencement of the rains.

2. FLACOURTIA, Commers.

Flacourtia Ramontchi, L'Hérit. Syn. *F. sapida*, Roxb. Vern. *Katái*, *bilangra*, *kukai*, *kanju*, *kakein*, Hind. ; *Paker*, *kaker*, Mar. ; *Hunmunki*, Kan. ; *Naywè*, Burm.

A small rather variable deciduous tree, usually thorny, with thin grey bark.

DISTRIBUTION AND HABITAT. Common throughout the greater part of India: in Burma it occurs in *indaing* and in dry forest. It is found in the lower scrub forests of the Rawalpindi hills associated with *Acacia modesta* and other dry zone species, thence eastward throughout the sub-Himalayan tract, both in sal forests and in the dry miscellaneous forests of the Himalayan valleys and outer hills up to 4,000 ft. Common throughout Chota Nagpur and the Indian Peninsula in mixed deciduous or scrub forests. In its natural habitat the absolute maximum shade temperature varies from 105° to 118° F., the absolute minimum from 25° to 50° F., and the normal rainfall from 30 to 85 in.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The tree is leafless usually just before or at the time of flowering, which occurs from December to March. The fruit, which ripens from March to July, is an edible berry, and the seed is spread by birds, which no doubt accounts in part for the wide distribution of the tree.

SILVICULTURAL CHARACTERS AND RATE OF GROWTH. The tree is somewhat frost-tender and is also readily browsed. It coppices fairly well, measurements made in the Gorakhpur division, United Provinces, showing the following production and rate of growth of stool-shoots as compared with sal in the same coupes:

		5 years old.	9 years old.
Average number of shoots per stool	{ <i>Flacourtia</i>	2.66	1
	{ Sal	1.28	1.35
Average height of coppice-shoots	{ <i>Flacourtia</i>	8 ft. 1 in.	9 ft. 0 in.
	{ Sal	9 ft. 2 in.	5 ft. 7 in.

Girth measurements in sample plots in the Lansdowne division, United Provinces, showed mean annual girth increments of 0.2 and 0.31 in., which indicates a slow rate of growth.

3. HYDNOCARPUS, Gaertner.

Hydnocarpus Wightiana, Blume. Syn. *H. inebrians*, Wall. Vern. *Kastel*, *kantel*, Mar.; *Toratti*, Kan.; *Maravetti*, Tam.

A large evergreen tree with brown, somewhat rough bark, and handsome shady foliage.

DISTRIBUTION AND HABITAT. Common in tropical forests along the Western Ghats from the Konkan southwards and below the *ghats* in Malabar and Kanara in moist situations, especially near water. Very common in Travancore up to 2,000 ft. Often planted. In its natural habitat the absolute maximum shade temperature varies from 94° to 99° F., the absolute minimum is about 60°, and the normal rainfall varies from 90 to 180 in. or more.

FLOWERING AND FRUITING. The tree flowers in February–March and the fruit, a large hard-rinded berry, ripens in May and June. The seeds (Fig. 8, *a*), which are 0.8–1 in. long, obtusely angular, are oily and do not retain their germinative power for long; they germinate during the rains shortly after reaching the ground. About 25 to 30 seeds weigh 1 oz.

GERMINATION (Fig. 8, *b-f*). Epigeous. The horny testa cracks with the swelling of the seed, exposing the soft whitish albumen, which encloses the

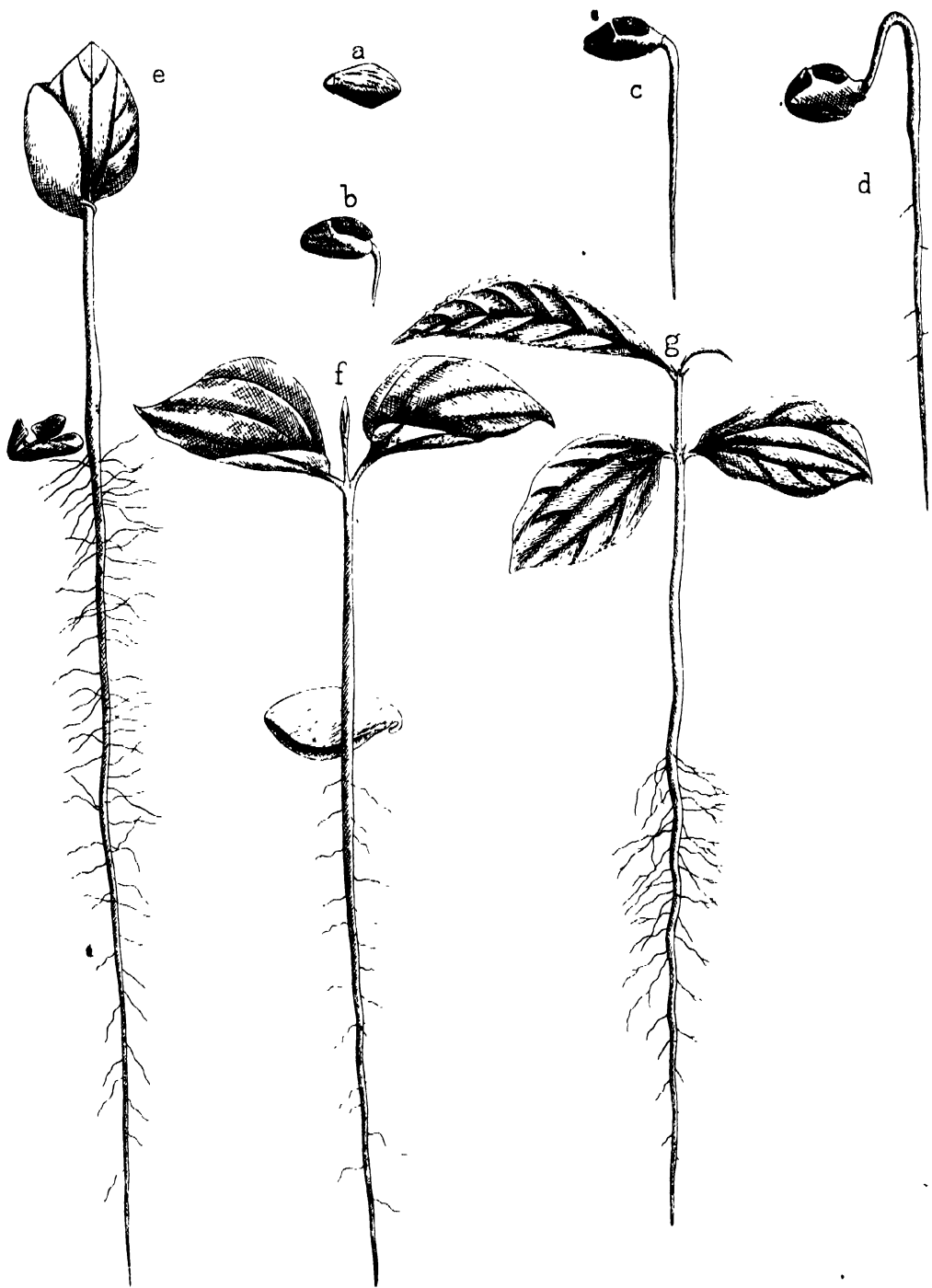


FIG. 8. *Hydnocarpus Wightiana*. Seedling $\times \frac{1}{2}$.
 a, seed. b-f, germination stages. g, seedling in first season.

cotyledons as in a bag until a taproot some inches long has been developed. The testa is usually left underground, while the albumen is carried up and dropped when the cotyledons expand.

THE SEEDLING (Fig. 8).

Roots : primary root long, moderately thick, woody, flexuose : lateral roots numerous, fibrous, distributed down main root. *Hypocotyl* distinct from root, 2.8–3.5 in. long, thick, terete, tapering upwards, green, glabrous. *Cotyledons* petiolate : petiole 0.25–0.3 in. long, channelled above, minutely pubescent : lamina 2–2.5 in. by 1.5–2.3 in., cordate or ovate, acute, entire, glabrous or minutely pubescent, palmately 5-veined. *Stem* erect, minutely pubescent ; early internodes 0.8–1.5 in. *Leaves* alternate, simple, petiolate. *Stipules* 0.1 in. long, triangular acuminate, pubescent. Petiole 0.2–0.3 in. long, channelled above, pubescent. Lamina 3–4 in. by 1–1.5 in. elliptical lanceolate, acute, base tapering, sharply serrate, glabrous or with minute hairs on main veins on under-surface ; venation arcuate, lateral veins 6–8 pairs in earlier leaves.

4. TARAKTOGENOS, Hassk.

Taraktogenos Kurzii, King. Vern. *Kalaw*, Burm.

A moderate-sized evergreen tree common in some of the tropical forests of Burma and also found in Assam. The seeds furnish the 'chaulmugra' oil used in the treatment of leprosy : this tree, though of economic importance, has not yet been studied silviculturally. In Assam it is reported not to seed well every year. The seeds are very oily, and soon lose their germinative power.

ORDER VI. TAMARICACEAE

TAMARIX, Linn.

Shrubs or small trees known as tamarisks, with small scale-like leaves. Some are interesting from their habit of springing up gregariously on newly formed alluvial land along rivers and by the sea-coast ; certain species, notably *T. dioica*, have a remarkable capacity for growing on saline soil, while several are characteristic of dry or arid regions where vegetation of any kind is scanty. The tamarisks exhibit xerophytic adaptations in the scale-like form of their leaves and in some cases in the shedding of the smaller twigs, as in *T. articulata*.

Mr. Hole, who is revising the Indian species of *Tamarix*, informs me that he has determined no fewer than ten species in Baluchistan alone. The commonest species of Sind and north-western India generally, hitherto known as *T. gallica*, he has found to be a new species which he has named *T. Troupii* ;¹ this species extends into Baluchistan, where it appears to be common. The true *T. gallica*, Linn., is not at present known to occur in India. *T. indica*, Roxb., is the common species of the Sundarbans and Madras. The largest of the commoner species is *T. articulata*, a moderate-sized tree of the Punjab plains, Sind, and Baluchistan. Perhaps the commonest species in the Indian Peninsula is *T. ericoides*, a handsome shrub with erect broom-like branches and much larger flowers and fruits than the other species, common in the rocky beds of rivers in the Peninsula and extending northwards to Chota Nagpur.

¹ Ind. Forester, xlv (1919), p. 247.

Species 1. *T. Troupii*, Hole; 2. *T. dioica*, Roxb.; 3. *T. articulata*, Vahl.

1. **Tamarix Troupii**, Hole. Vern. *Lai, jhau*, Sind; *Jhau*, Hind.; *Pilchi*, Punjab; *Ghazlei*, Baluch.

A glaucous gregarious shrub or small tree with crooked stem, pendulous branches, and light grey smooth bark. The wood, which is not durable, is used for temporary poles and rafters: it is extensively used as fuel, and ranks third among the fuel woods of Sind, where it is employed in locomotives and steamers as well as for domestic use. The brushwood is largely used for protective works along the Indus. The astringent galls are used as a mordant in dyeing.

On saline soil or water-logged ground the growth is bushy and dwarfed, but on better soils this species develops into a fair-sized tree, attaining a maximum height of 30 ft. and a girth of 3 ft., although the average height attained is nearer 20 ft.

DISTRIBUTION AND HABITAT. United Provinces, Punjab, Sind, extending into Baluchistan. Like certain other species of *Tamarix*, this species is able to flourish in regions with scanty rainfall and extremes of temperature. In those parts of Sind where *T. Troupii* and *T. dioica* are common the absolute maximum shade temperature varies from 120° to 125° F., and the absolute minimum from 26° to 40° F., while the normal rainfall varies from under 3 in. to about 13 in. In the case of these two species, however, the water provided by river floods counteracts to some extent the effect of the dry climate. Elsewhere they occur in regions with less marked extremes of temperature and with a rainfall up to 70 in. or more.

The origin of alluvial *Tamarix* forests is typically illustrated along the banks of the Indus in Sind, where this species and *T. dioica* form extensive forests. The newest so-called *kacha* alluvium thrown up by the river and submerged by the annual floods for several feet each year, until raised above the surface of the water by successive deposits of silt, becomes covered in the first place by multitudes of tamarisk seedlings which, provided the soil is not pure sand, soon establish themselves in a dense crop mixed with *kanh* grass (*Saccharum spontaneum*), the grass being killed out subsequently by the tamarisk. As the land becomes more elevated, but still subject to annual floods, *Populus euphratica* and *Acacia arabica* take possession of the ground. Later on, when the land becomes more elevated, and not subject to any but abnormal floods, *Prosopis spicigera* becomes the prevailing species. As these successive species invade the ground the tamarisk becomes gradually suppressed and killed out, though in places even on the older high land crops of *Prosopis* are found with an undergrowth of tamarisk still struggling against lack of water, and often mixed with the typically semi-desert shrub *Capparis aphylla*. In this way it may persist through all successive stages of alluvial forest growth from the pure bushy tracts of tamarisk on the new *kacha* ground to the high-lying older dry alluvium which has become invaded by *Prosopis*.

In its earlier stages the tamarisk is subjected to periodical flooding. It withstands partial submergence without suffering, but complete and continuous submergence for several days kills it. Hence, until the new alluvium reaches the stage of becoming free from complete submergence for any but short periods of time, the young crop cannot be said to have established itself. In

its youth the tamarisk has further to contend against the fierce fires which rage through the *kank* grass with which it is mixed; this grass, which dries up early in the year, is systematically ignited by graziers in search of fresh young grass, the dangerous fire-season being January till April.

The later development of the plant depends largely on the nature of the soil: on stiff clay or on pure sand it tends to remain stunted, while on good alluvial loam sufficiently retentive of moisture it develops into a small tree: the densest crops and the largest plants are usually found in moist silted depressions in old river channels, provided the soil is not too stiff. In these riverain tracts land which has risen above the level of the annual floods often becomes saline, a white efflorescence on the surface, locally known as *kalar*, indicating deterioration of the soil owing to the lack of surface irrigation. The tamarisk persists for a time on such ground, but does not thrive and gradually dies out. In favourable localities *T. articulata* is sometimes associated with the other two species.

Along the Indus the tamarisk crop is of great importance in sheltering from the effects of frost the tender seedlings of the more valuable *Acacia arabica*, which spring up under its shelter from seed brought in by grazing animals, and which are often killed off if they spring up in the open.

FLOWERING AND FRUITING. The paniced spikes of white or pink flowers, which are usually bisexual, appear from July to November, and the capsules ripen and the small seeds are shed from December to February.

SILVICULTURAL CHARACTERS. This plant is a strong light-demander, and will not tolerate the shade of other species; it is hardy, withstanding ordinary frosts. It coppices vigorously, but does not produce root-suckers. It is easily propagated from cuttings. The stem is readily destroyed by fire, but the plant has good power of recovery from the base. It is not much subject to injury by cattle or browsers.

NATURAL REPRODUCTION. In Sind the light seeds are spread by wind and water, and natural reproduction springs up in great profusion on newly formed alluvium: the seed germinates rapidly, and the seedlings establish themselves quickly.

SILVICULTURAL TREATMENT. In Sind the tamarisk is treated in conjunction with *Acacia arabica*, *Populus euphratica*, and *Prosopis spicigera*. Usually the treatment applied to the tamarisk is that of clear-felling with coppice reproduction, while on the new alluvial land seedling reproduction is relied on. Ordinarily a rotation of fifteen years has been adopted hitherto, this being found sufficient to produce the size of fuel billets required. The rotation, however, has recently been increased to thirty years, the importance of the tamarisk being insufficient to justify its being worked on a different rotation from that adopted for *Acacia arabica*, the principal species in Sind. The tamarisk is clear felled along with the principal species, and regenerates by stool-shoots or, where conditions are favourable, from seed.

RATE OF GROWTH. The rate of growth is rapid. Measurements recorded by Mr. A. C. Robinson in the Jerruck division, Sind, showed that the mean annual girth increment for fifteen years in the case of seedling plants was 1.36 in., so that for a rotation of fifteen years the average girth attained is 1 ft. 8.4 in., corresponding to a diameter of 6½ in. The maximum growth

recorded was a diameter of 10.5 in. attained in sixteen years, representing a mean annual girth increment of 2.06 in., which is rapid. Strictly speaking, the tree is mature at this age or even earlier, since the base of the stem tends to become hollow by the time an age of fifteen years is reached.

2. *Tamarix dioica*, Roxb. Vern. *Lai, gaz, lao, jhau*, Sind; *Lal jhau*, Beng.; *Jhau*, Hind.; *Lai, pilchi*, Punjab; *Byaung-chedauk*, Burm.

A glaucous gregarious shrub or small tree with pendulous branches and reticulately fissured bark. This plant is very similar to *T. Troupii*, with which it is sometimes associated: it is, however, usually smaller and has greyer foliage and broader flower-spikes.

DISTRIBUTION AND HABITAT. Throughout northern India up to 2,500 ft. in the outer Himalayan valleys, Sind, the Peninsula of India, Bengal, Assam, Santal Parganas, and in the dry zone of Burma, chiefly on sand-banks and in river-beds. It is common along the Ganges, Hooghly, and other rivers, and forms extensive forests along the Indus in Sind. It is also found along the sea-coast. It is common in the sandy or shingly beds of some of the streams issuing from the hills in the sub-Himalayan tract.

A description of the tamarisk forests along the Indus in Sind has been given under the preceding species. In this tract *T. dioica* usually occupies different ground from *T. Troupii*, for although the two are often found together *T. dioica* is largely confined to the high and saline lands which are seldom, if ever, subject to inundation: it is very commonly found on soils heavily impregnated with salts, and has remarkable capacity for existence on such ground.

FLOWERING AND FRUITING. The panicle spikes of dioecious pink flowers appear from May to August, and the small capsules ripen in the cold season.

SILVICULTURAL CHARACTERS. The silvicultural characters of this plant are similar to those of *T. Troupii*, except that it has greater capacity for growing on saline soil.

RATE OF GROWTH. The rate of growth is rapid. The figures quoted under *T. Troupii* for the Jerruck division, Sind, include this species also. Mr. Minniken's report of 1878 on the Delhi Bela plantation records an average growth of 1.4 rings per inch of radius, equivalent to a mean annual girth increment of 4.48 in., which is extremely rapid.

3. *Tamarix articulata*, Vahl. Syn. *T. orientalis*, Linn. Vern. *Farásh*, Punjab; *Asrelei*, Sind.

A small to moderate-sized tree with feathery foliage, an erect tapering trunk, and rough grey bark, attaining a height of 60 ft. and a girth of 6-7 ft. or more. The foliage is greyer and more glaucous than that of the previous two species, the twigs being often covered with a saline efflorescence. An important tree in arid regions, the wood being used for agricultural implements, turning, and other purposes, as well as for fuel.

DISTRIBUTION AND HABITAT. The Punjab plains, Sind and Baluchistan, extending westward to Egypt. It thrives in arid regions with extremes of temperature, where the thermometer reaches a shade temperature of 120° F. or more in the hot weather, while in the winter it sinks below freezing-point; the rainfall in parts is as low as 3 in. The tree is common on the Punjab plains from Delhi to Peshawar and Multan, often associated with *Prosopis*

spicigera, *Salvadora oleoides*, *Capparis aphylla*, and other species characteristic of these dry regions: it is uncommon in Lower Sind. It thrives best on loam, though it is found also on stiff clay and on sand, while it is capable of growing on saline soils provided there is surface irrigation: it cannot tolerate soil heavily impregnated with salts. It grows more vigorously on land subject to occasional inundation than on land which is never flooded: it is, however, not typical of the new *kacha* alluvium on which *T. Troupii* habitually and *T. dioica* more rarely springs up.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The leaves and extremities of the branchlets are shed in part during the cold season, the new shoots and leaves appearing about May. The small flowers, loosely arranged on long slender spikes, appear from May to July, and the small capsules ripen in the cold season. The seeds are minute.

SILVICULTURAL CHARACTERS. This tree is a hardy one, standing extremes of temperature as well as excessive drought. It withstands ordinary frosts, but in the abnormal frost of 1905 in northern India it suffered to some extent. It coppices freely, sending out quantities of shoots, and grows readily from cuttings, but does not produce root-suckers. Inundations do not harm the coppice as in the case of *Prosopis spicigera*: in the Punjab, however, the coppice-shoots suffer from the attacks of a fungus which causes many of them to decay before they reach marketable size. The tree is browsed by camels.

NATURAL REPRODUCTION. As a rule reproduction from seed is fairly good, but it is doubtful if it is ever thoroughly successful except on land liable to occasional inundation or the accumulation of rain-water. Thus in the Punjab plains in tracts where this tree occurs it is found principally on the more low-lying areas, the higher ground being occupied mainly by *Prosopis spicigera* and other species.

ARTIFICIAL REPRODUCTION. Plants may be raised from seed in nursery beds, but special precautions are necessary owing to the small size of the seeds, which should be mixed with fine moist sand, the mixture being spread over the surface of the beds. The latter should be not more than 2 ft. wide, with a trench on either side which is flooded periodically in order to moisten the beds by percolation; the beds should not be watered by hand. The seed should be sown about January, when it ripens, the seedlings being pricked out in the nurseries when 3 or 4 in. high: the stronger plants may be transplanted during the first rains, but as a rule it will be preferable to defer transplanting till the beginning of the following rains.

Propagation by cuttings is easier and more satisfactory: this system is commonly adopted in Sind in cases where afforestation is undertaken along with the raising of *kharif* field crops. Cuttings as thick as the finger and about 16 in. long should be planted slightly out of the vertical to a depth of 12 in. in prepared nursery beds in February or early March, and the beds should be watered regularly: the cuttings will be well rooted and ready to transplant by August of the same year.

SILVICULTURAL TREATMENT. The tamarisk, along with its associates, is commonly worked as coppice, the rotation adopted being twenty to twenty-five years in order to produce fuel billets up to 10 in. or over in diameter.

VI. TAMARICACEAE

RATE OF GROWTH. The growth is rapid. Mr. McIntire records the following results of measurements of coppice-shoots in Multan district :

Age of coppice. years.	Diameter. in.	Out-turn of material over 2 in. in diameter per stool. cubic ft. stacked.
5	2 to 4	1 to 2
10	4 to 7	3 to 15, av. 8
15	6 to 10	5 to 25, av. 15
20	7 to 12	8 to 40, av. 25

The growth is much faster on low-lying ground subject to inundation than elsewhere.

Brandis says that trees 12 years old on an average attain a girth of 2-3 ft., and that a tree 15 years old measured 4 ft. 10 in. in girth. In Baluchistan various measurements in coppice coupes have been recorded in recent years. These apply at least in part to this species, but probably other species are included as well. In the Popalzai state forest coppice-shoots 7 months old had a minimum and maximum height of 2½ ft. and 5 ft. respectively, while those 1½ years old had an average height of 6 ft. Measurements made from 1910-11 to 1915-16 in coppice coupes in the Abdulla Kheli and Nari Bank forests gave the following results :

Age in years.	Maximum height.
1	12 ft. 9 in.
2	16 ft. 6 in.
3	15 ft. 0 in., and 17 ft. 0 in.
4	17 ft. 0 in., 19 ft. 0 in., and 20 ft. 9 in.
5	19 ft. 0 in., 22 ft. 6 in., and 27 ft. 0 in.
6	17 ft. 0 in., 22 ft. 6 in., and 27 ft. 0 in.
7	19 ft. 2 in., 22 ft. 9 in., and 27 ft. 0 in.
8	22 ft. 6 in., 22 ft. 9 in., and 27 ft. 8 in.
9	22 ft. 6 in., and 27 ft. 0 in.
10	22 ft. 11 in.
11	22 ft. 8 in.

These figures indicate that for the first few years the growth is very rapid, but that it soon begins to fall off: the trees originally felled had a maximum height of 30 ft.

ORDER VII. GUTTIFERAE

An important order of trees, chiefly evergreen, with opposite glabrous, usually leathery leaves. The trees are characteristic mainly of tropical evergreen forests, and include some useful timber-yielding species. Several of the numerous species of *Garcinia*, which are characteristically shade-bearing, furnish the pigment known as gamboge, which is exuded from cut surfaces in the cortex in the form of a yellow resinous juice: some of the species produce edible fruits, notably *G. Mangostana*, Linn., the mangosteen. Of timber trees the most important are *Mesua ferrea*, Linn., *Poeciloneuron indicum*,

Bedd., and some of the species of *Calophyllum* which furnish timber used for masts and spars.

Genera 1. *CALOPHYLLUM*, Linn.; 2. *POECILONEURON*, Bedd.; 3. *MESUA*, Linn.

1. *CALOPHYLLUM*, Linn.

Evergreen trees with shining coriaceous leaves. Besides the two described below may be mentioned *C. polyanthum*, Wall., of the moist forests of northern and eastern Bengal, Assam, Chittagong, and the Martaban hills; *C. Wightianum*, Wall., of the Western Ghats, often on the banks of streams; and *C. spectabile*, Willd., a tall tree of Tenasserim and the Andamans.

Species 1. *C. tomentosum*, Wight; 2. *C. Inophyllum*, Linn.

1. *Calophyllum tomentosum*, Wight. Syn. *C. elatum*, Bedd. Poon. Vern. Poon, Mal.; Pongu, Tam.; Nagari, Mar.; Surhoni, siri, poone, bobbi, Kan.

A very large evergreen tree with a straight cylindrical stem. Bark yellowish, with long wavy vertical fissures which readily distinguish the species (Talbot). According to Talbot it attains a great size in North Kanara, where trees 150 ft. high with a girth of 15 ft. at breast height are not uncommon. The timber is used for masts and spars and in bridge construction, but trees are far less plentiful than formerly, having been largely cleared for coffee plantations last century, as well as sought after for masts and spars.

DISTRIBUTION AND HABITAT. Western Ghats from North Kanara southwards, both on the western slopes and in Mysore and Coorg, the Palni and Anamalai hills up to 5,000 ft., always in moist evergreen forest and 'sholas', never in dry deciduous forest. Talbot says that in North Kanara it is practically restricted to the forests about Mulamane on the Gairsoppah Ghat, where it is locally common. In its natural habitat the absolute maximum shade temperature varies from 90° to 100° F., the absolute minimum from 40° to 60° F., and the rainfall from 80 to 170 in. or more.

FLOWERING AND FRUITING. The white scented flowers appear in February–March, and the fruit, an ovoid drupe about 1 in. long, ripens in May–June.

SILVICULTURAL CHARACTERS. The tree is a shade-bearer: it is sensitive to fire, and is encouraged by fire-protection. The seed germinates early in the rains, soon after falling, and the seedlings appear freely in the shade of the overhead cover.

2. *Calophyllum Inophyllum*, Linn. Alexandrian laurel. Vern. *Sultana champa*, Hind.; *Pinnai*, *punnai*, Tam.; *Undi*, Mar.; *Wuma*, Kan.; *Punna*, Tel., Mal.; *Pônnyet*, Burm.

A moderate-sized very ornamental evergreen tree with short thick, often crooked bole, dark brown or blackish bark, handsome white flowers, and dense dark green shiny foliage. It furnishes a useful timber, and the seeds yield an oil used for burning.

DISTRIBUTION AND HABITAT. Along the east and west coasts of the Indian Peninsula, Burma, and the Andamans. It is essentially a littoral species, growing down to the edge of the sea. It grows best on deep soil near the coast, and will thrive on pure sand. Talbot says it is common in North Kanara on the sandy coast laterite soil just above high-water mark, often associated with *Anacardium occidentale*, *Salvadora persica*, *Erythrina indica*,

Ficus tomentosa, *Pongamia glabra*, and other littoral species. In the Andamans it is characteristic of the mixed forests of the littoral fringe on raised beaches or deposits of sea sand; here it is found associated with *Afzelia bijuga*, *Mimusops littoralis*, *Thespesia populnea*, *Terminalia Catappa*, *Pongamia glabra*, *Erythrina indica*, *Hibiscus tiliaceus*, *Heritiera littoralis*, and other species.

FLOWERING AND FRUITING. According to Talbot, in North Kanara the white flowers appear in the cold season, and the fruit, a yellow or green drupe about 1-1½ in. in diameter, ripens about March. Bourdillon says that in Travancore the flowers appear in March-April and the fruits ripen in May-June, but that flowers and fruits are found at other seasons, as the tree has one large and two small crops every year. About 6 fruit-stones weigh 1 oz.; the seeds are very oily, quickly losing their germinative power. The fruits are readily eaten by bats, which disseminate the seeds.

SILVICULTURAL CHARACTERS. The tree is said to be brittle and liable to damage by wind. It can be raised without difficulty from seed provided the seed is sown soon after ripening.

2. POECILONEURON, Bedd.

Poeciloneuron indicum, Bedd. Vern. *Balgi*, *kirballi*, Kan.; *Puthan kolli*, Tam.

A large evergreen tree with a fairly straight bole, which attains a girth of 10 ft. or more. The larger trees are often buttressed, and sometimes have the appearance of being raised above the ground owing to the soil having been washed away from around the roots. It has a very hard dark red wood, which is used for building and has given fairly good results for railway sleepers.

DISTRIBUTION AND HABITAT. Evergreen forests of the Western Ghats from South Canara southwards, from 1,500 to 4,000 ft. In South Canara it extends over the crest of the *ghats* into Mysore, where it is common in the adjacent forests. Mr. Foulkes notes that in South Canara it is for practical purposes found only in certain sharply defined patches aggregating nearly 2,300 acres and situated mainly on the *ghat* slopes. Bourdillon says that it is common in the south of Travancore at elevations of 1,000-3,000 ft., but less common in the north, and that it is generally found in clumps growing on wind-swept ridges. The tree grows more or less gregariously, sometimes forming almost pure crops. Mr. Foulkes estimated, from partial enumerations in 1902, that in 2,300 acres in South Canara there were some 11,400 mature trees 2 ft. in diameter and over, distributed at the rate of 0.2 to 8.5 mature trees per acre. Mr. Gass records the following results of countings made in 1898 in three plots of 1 acre each:

- | | | | | | | | | | | | | |
|-----|-------|-----|--------|---------|----|-------|------|---|-----|----|----|-------------------|
| (1) | Total | 158 | trees, | varying | in | girth | from | 1 | ft. | to | 10 | ft. |
| (2) | " | 291 | " | " | " | " | " | " | " | " | 1 | ft. to 6 ft. |
| (3) | " | 79 | " | " | " | " | " | " | " | " | 1 | ft. to over 6 ft. |

The first plot was in Mysore, and the other two were in South Canara.

In the natural habitat of this tree the absolute maximum shade temperature varies from 90° to 98° F., the absolute minimum from 48° to 60° F., and the normal rainfall from 80 to 180 in.

FLOWERING AND FRUITING. The yellowish-white flowers in terminal

panicles appear from December to April, and the fruit ripens from June to August. The seeds appear to lose their vitality quickly: seeds received from South Canara in 1912 had for the most part gone bad by the time they reached Dehra Dun, and although 24 selected seeds were sown at once, only 3 proved fertile. Bourdillon says it seeds freely and reproduces well in Travancore.

THE SEEDLING. The seeds just referred to were sown in open seed-beds in July, and germinated $1\frac{1}{2}$ months later. At first the growth of the seedlings was rapid, a height of 7 in. being reached in ten days. Afterwards growth was slow, and the seedlings suffered from frost in the winter, when growth ceased. New growth commenced in May, but the plants died off in July. In their early stages the seedlings have a resemblance to those of the mango, except that the leaves are more leathery and the venation is not so well marked.

SILVICULTURAL CHARACTERS. The tree is a shade-bearer. It reproduces abundantly from seed, and also coppices well. It is very sensitive to fire, and benefits greatly from fire-protection.

3. MESUA, Linn.

Mesua ferrea, Linn. Syn. *M. coromandelina*, Wight; *M. pedunculata*, Wight; *M. speciosa*, Choisy; *M. Roxburghii*, Wight; *M. sclerophylla*, Thw.; *M. pulchella*, Pl. and Trian. Ironwood of Assam. Vern. *Nahor*, Ass.; *Nageswar*, Beng.; *Naga kesara*, Tel.; *Nagchampa*, Mar.; *Naga-sampige*, Kan.; *Atha*, Coorg; *Nangal*, Tam.; *Gangaw*, Burm.

A moderate-sized to large handsome evergreen tree, often buttressed at the base, with a dense conical crown of glossy leaves, their under surface glaucous with a waxy bloom. Bark fairly thin, reddish brown, red within, exfoliating in flat thin flakes. Wood dark red, extremely hard, very strong, durable but sometimes liable to dry rot, used for railway sleepers, bridge-construction, and many other purposes.

DISTRIBUTION AND HABITAT. The western Duars, Assam, Khasi hills, Chittagong, Upper Burma, Tenasserim, Andamans, hills of western and southern India. Often cultivated, especially round Buddhist monasteries. In the Duars the tree is very local, a patch occurring in the Upper Tondu forest of the Jalpaiguri forest division and another in the Tista division; the latter is probably the western limit of this species in the Bengal-Assam tract. In the Abor country it exists in small quantities in the Dihong valley (Milroy). In Bhutan it occurs to a limited extent among the low hills east of the Manas river (Jacob). In Upper Burma it is found wild, as far as is known, only in the far north, while it is said to be common in parts of Tenasserim. In the Indian Peninsula it is found in limited quantity in the tropical evergreen forests of the Western Ghats from North Kanara southwards. It is more abundant in Assam than elsewhere, and is found in suitable localities throughout that province, where it is one of the most important timber trees: in the Brahmaputra and Surma valleys it occurs at various elevations from the level of the plains up to nearly 3,000 ft. In the Andamans it is common on some of the higher hills, in evergreen forest.

Mesua ferrea is a tropical or semi-tropical tree: in its natural habitat the climate is moist, warm, and equable, the rainfall varying from 80 to 200 in.

or more, the absolute maximum shade temperature from 95° to 103° F., and the absolute minimum from 40° to 60° F.

The tree occurs on flat, gently undulating, or hilly ground, but not on low-lying badly drained land. It requires good drainage as well as a deep moist fertile soil: stiff clay is unsuitable. In Assam it occurs in the Sibsagar district on deep rich loam both on well-drained flat alluvial ground at an elevation of 310 ft., and on gently undulating ground with a subsoil of ferruginous gravel or sandstone. In the Jokai reserve, Lakhimpur, it is found in abundance on fertile sandy loam at an elevation of 450 ft. on well-drained flat alluvial ground raised above the level of river floods. In the Garo hills it forms a belt along the slopes of the central range at elevations of 1,000 to 3,000 ft., chiefly in damp sheltered localities on deep loam resulting largely from the decomposition of metamorphic rocks. In Burma it occurs in similar localities on metamorphic or sandstone formations.

Mesua ferrea is characteristically found in moist evergreen or semi-evergreen forest, either scattered or in more or less pure patches or belts of greater or less extent. It is associated with a large number of different species, many evergreen and some deciduous; in Assam some of the chief of these are *Artocarpus Chaplasha*, *Amoora Wallichii*, *Cedrela Toona*, *Quercus lanceaefolia*, *Alstonia scholaris*, *Dysoxylum binectariferum*, *Sterculia alata*, *Dichopsis polyantha*, *Gmelina arborea*, *Lagerstroemia Flos-Reginae*, *Terminalia myriocarpa*, *T. Chebula*, *Stereospermum chelonoides*, *Eugenia Jambolana*, *Dillenia indica*, *Cinnamomum Cecidodaphne*, *Dipterocarpus pilosus*, *Shorea assamica*, and many others. There is often an evergreen undergrowth, while climbers are prevalent. In the Assam forests the proportion of *Mesua* (locally called *nahor*) to other species may vary considerably. In the Nambor reserve, Sibsagar, Mr. A. R. Dicks has estimated that it forms 5 per cent. of the crop on the high alluvium on which it occurs. In the working plan for the Jokai reserve, Lakhimpur, Mr. F. H. Cavendish states that the tree occurs only on the higher alluvium, where it is found in almost pure patches up to 100 acres or more in area, which gradually merge into mixed evergreen forest. He divides the forest on this ground into three classes as follows:

(1) *Nahor* dominant, forming 30–80 per cent. of the stock: about 1,000 acres.

(2) Evergreen forest in which *nahor* is scattered more sparsely: about 500 acres.

(3) Evergreen forest containing a mixture of various species where *nahor* is hardly found: about 2,100 acres.

In this forest a complete enumeration of *nahor* trees over 709 acres where this was the dominant species gave the following results:

Trees over 6 ft. in girth	.	.	.	.	.	192 or 0.27 per acre
„ 4–6 ft. in girth	.	.	.	.	.	1,857 or 2.6 „ „
„ 2–4 ft. in girth	.	.	.	.	.	7,660 or 10.8 „ „

Saplings and seedlings below 2 ft. in girth numerous.

Peal, quoted by Gamble, gives the following account of the spread of the *nahor* in Assam from trees planted by the Burmese when they occupied that province: 'The forest, if properly studied, often yields information of a peculiar

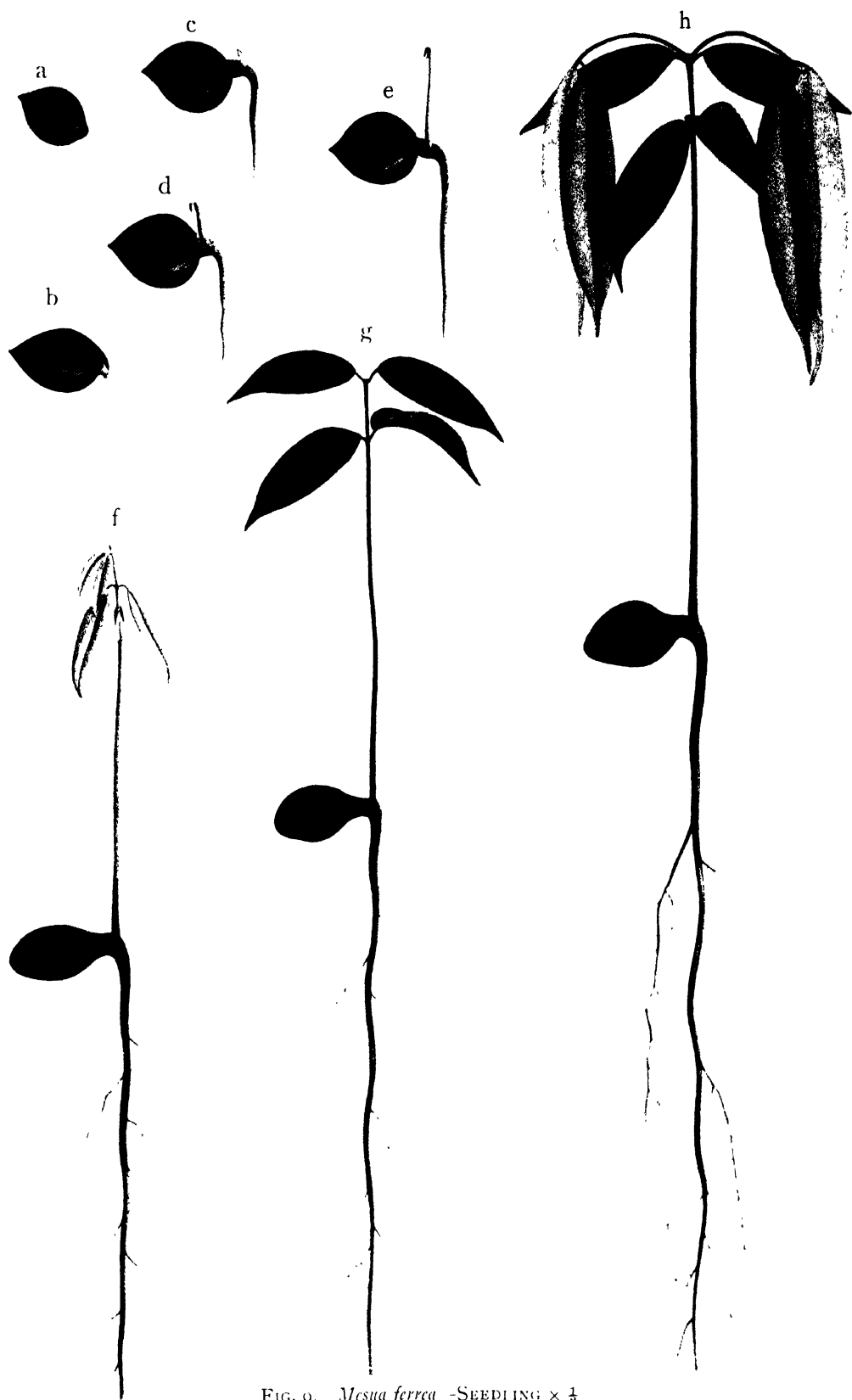


FIG. 9. *Mesua ferrea* -SEEDLING $\times \frac{1}{2}$
 matation stages f, g—Development of seedling to end of first season

kind: thus the *nahor* gives a clue to the density of the population compared to what we see now. The large, old, and crooked branching *nahor* trees clearly indicate that when young the country now forest was then open. They are often along the sides of old "bunds" (embankments) in dense forest, and evidently planted, and from the seed the *nahor* forest has sprung up, and it is generally as straight as the old trees are the reverse.'

LEAF-SHEDDING, FLOWERING, AND FRUITING. The old leaves fall during the cold season, and the new flush of red or pink leaves appears towards the end of that season, usually from about the end of February in Assam. The large scented white flowers, 2 in. or more in diameter, with numerous prominent yellow stamens, appear from the end of February to April, or in Assam up to May or even June (January–April in Travancore, Bourdillon); when the tree is in flower it is a gorgeous sight with its masses of white blossoms, which are visited by innumerable bees and other insects. The time at which the fruit ripens appears to vary. Talbot says May (North Kanara), Kurz says May–June (Burma), and Bourdillon says October–March (Travancore). In Assam it ripens from August to October. The fruit is ovoid, pointed, somewhat woody, about 1–1.5 in. long, two-valved, containing 1–4 seeds. The seeds (Fig. 9, *a*) are 0.8–1.1 in. long, ovoid or irregularly hemispherical, pointed, with angular sides, smooth, reddish brown; testa hard but somewhat brittle. About 150–200 seeds weigh 1 lb. The seeds are very oily and soon lose their vitality. The tree ordinarily commences to produce fertile seed at from fifteen to twenty years of age. Isolated trees flower and seed abundantly almost every year, while in the forest good seed-years take place at frequent intervals.

GERMINATION (Fig. 9, *b-e*). Hypogeous. The testa of the seed splits and the radicle emerges from the blunter end and descends. Meanwhile the cotyledonary petioles elongate rapidly, enabling the plumule to emerge and ascend. The fleshy cotyledons remain below the ground within the testa, remaining attached to the seedling for several months and supplying it with nutriment.

THE SEEDLING (Fig. 9).

Roots: primary root moderately long, thick, terete, tapering, brown, wiry; lateral roots numerous, long, fibrous, much branched. *Hypocotyl* scarcely distinguishable from root, 0.1 in. long or less, stout, subterranean. *Cotyledons* petiolate, subterranean, remaining within the testa: petiole 0.2–0.3 in. long, thick, at first fleshy, afterwards woody, inner surface flattened: lamina 0.9–1.1 in. by 0.6–0.8 in., thick, fleshy, and oily, unequally ovate, outer surface rounded, inner flattened in contact. *Stem* erect, terete, wiry, green, glabrous; first internode, between cotyledons and first foliage leaves, 4–7 in. long, subsequent internodes much shorter, about 0.7–1.5 in.; new shoots likewise commence with a long internode, subsequent internodes being shorter, up to 2.5 in. in seedlings of the second year. *Leaves* simple, opposite, exstipulate; first few usually rudimentary and scale-like. Petiole 0.2–0.3 in. long, glabrous. Lamina 1.7–4 in. by 0.6–0.9 in., elliptical lanceolate, acuminate, base acute, entire, coriaceous, dark green and shining above, glaucous beneath with a waxy bloom; young leaves delicate, drooping, pink or pale green; venation pinnate, midrib distinct, lateral veins numerous, fine, and close together, running nearly at right angles to midrib.

The growth of the seedling is slow to moderate, a height of 6–10 in. being ordinarily attained in the first season, while thereafter the growth is at the

rate of a few inches up to about a foot a year. The seedling stands a considerable amount of shade, but dislikes suppression by weeds. It is sensitive to cold and drought, and under forest conditions demands shelter from the sun.

SILVICULTURAL CHARACTERS. *Mesua ferrea* is a strong shade-bearer, particularly in youth. Frost is practically unknown in the natural habitat of the tree, and in the sheltered position in which the young plants grow they are never exposed to the risk of frost. If planted outside its natural habitat in places subject to frost, it has been found to be very tender, and the same applies as regards drought. Fire does not ordinarily occur in the type of forest in which it is found. In certain localities the trees are subject to the attacks of what is believed to be a root fungus, which kills them off in groups: so far the sporophores have not been found, and the fungus has not been specially studied or identified.

The coppicing power of the tree appears to vary. In coppice coupes in Assam it is reported not to coppice freely. Rai Bahadur Upendranath Kanjilal informs me that trees coppiced in the Holangapar reserve, Sibsagar, which were from 12 to 24 in. in girth, entirely failed to coppice. On the other hand, Jageswar Sur wrote in 1883¹: 'That *nageswar* coppices freely admits of no doubt, and I have seen a young tree when burnt down throw out strong shoots from the collum. Again, I once tried to kill three young plants growing in front of a rest-house at Kulsī by cutting them flush with the ground, but as often as they were cut back they threw out new shoots. A tree 15 years old in a garden at Calcutta was felled, and the stool sent up new shoots.'

NATURAL REPRODUCTION. In forests where it occurs *Mesua ferrea* regenerates more profusely than almost any of its associates, partly because of its abundant seeding, and partly owing to the capacity of the seedlings for standing, and even requiring, a considerable amount of shade. The essential conditions for germination and early development are a high degree of moisture and protection from the sun: seeds lying in the open exposed to the sun soon crack and go bad. A good seed-year does not necessarily result in plentiful regeneration, since the seed is liable to the attacks of weevils, and the seed crop may suffer seriously in consequence. On the ground the seeds are readily devoured by pigs, porcupines, and other animals, and where this is permitted they are also collected by the local inhabitants for burning. The oily seeds are strung like beads on a thin piece of split bamboo and then lighted, when they burn like a candle. Mr. Kanjilal notes that in Sibsagar natural reproduction takes place freely in swampy localities under the cover of dillénias and laurels, the seed being deposited by water, and that judging by the ages of the seedlings, profuse regeneration takes place every four or five years. Two important factors for successful reproduction are a dominant condition of the seed-bearers and freedom of the seedlings from suppression by a dense undergrowth or masses of climbers. Where the *nahor* trees are dominant, with free well-developed crowns capable of producing a plentiful crop of seed, there is usually no difficulty in obtaining sufficient regeneration, but where they form an under-story to larger trees of other species and owing to their dominated position are unable to produce seed in quantity, the regeneration is usually poor. This indicates the necessity for carrying out thinnings in the

¹ Ind. Forester, ix (1883), p. 609.

overwood, together with climber-cutting, in order to free the crowns of the *nahor* seed-bearers. Again, where, as is often the case, there is a thick evergreen undergrowth or an under-story of various poles and shrubs covered with a dense mass of climbers, although *nahor* seedlings and saplings are capable of struggling amongst this dense growth to a remarkable extent, systematic climber-cutting and cleaning has proved to be most beneficial to the establishment of this regeneration. In general, then, it may be said that there is no difficulty in obtaining ample natural regeneration by means of systematic thinnings and climber-cutting, with cleaning in the undergrowth where necessary. With this assistance the shade-bearing *nahor* seedlings and saplings have no difficulty in competing successfully with their faster-growing but more light-demanding associates.

ARTIFICIAL REPRODUCTION. The only available record of a forest plantation of *Mesua ferrea* is that formed at Ohguri in the Nambor reserve, Sibsagar division, Assam, between the years 1876-7 and 1882-3. This plantation, which never justified the expenditure on it, was eventually abandoned. It was formed by sowing seeds of *Mesua ferrea*, *Lagerstroemia Flos-Reginae*, and *Cedrela Toona* in lines 6 ft. apart: the proportion of each species sown is not known. In 1903 Mr. Dicks reported that the plantation, the average age of which was then twenty-four years, was very densely stocked with young poles, but that the *Lagerstroemia* greatly outnumbered the *Mesua*: presumably the *Cedrela* did not succeed. Neglecting what were obviously pre-existing natural saplings from neighbouring seed-bearers, the average girth of the dominant and sub-dominant trees was found to be 2 ft. Most of the trees above 2 ft. in girth were found to have seeded.

Considering the facility with which natural reproduction can be secured, the experience gained from this plantation indicates that the meagre success attained would hardly justify such a form of artificial reproduction on a large scale, though it is possible that seed dibbled under the shade of forest of suitable type, if this could be done cheaply, might be a means of extending the area of *nahor* forest where this species is absent or scanty.

The raising of plants for planting out along roadsides or in gardens presents no special difficulty. The seed should be sown as soon after collection as possible and well covered with earth in the nursery beds; the latter should be in a shady situation and should be kept moist, care being taken to avoid caking of the soil. A fairly long stout taproot is developed by the seedling, but with ordinary care there is no special difficulty in transplanting, which may be carried out from the first to the third rains after sowing, according to the size of plants required. Watering should be carried out in the dry season for at least two years after transplanting.

SILVICULTURAL TREATMENT. In Assam it has been usual to work the forests containing *nahor* under selection and improvement fellings in which this tree is the one most favoured. In selection fellings a minimum girth limit of 6 ft. is commonly adopted, the corresponding age being assumed to be ninety years. From what has been mentioned above under 'natural reproduction', it is obvious that systematic freeing of *nahor* trees in the overwood, combined with climber-cutting and with cleaning where necessary in the underwood, is a great stimulus to the establishment of natural reproduction,

and the concentration of such operations for certain periods over definite manageable blocks is likely to increase considerably the proportion of this valuable species. The dibbling of seed where *nahor* is sparse or absent has been suggested above.

RATE OF GROWTH. Observations of trees planted in gardens show that the rate of growth is decidedly slow. Authentic statistics for forest use are scanty, and until the results of periodic measurements in sample plots are available they will remain so. Concentric rings of darker tissue, it is true, are visible on a cross-section, but they cannot be relied on for furnishing accurate data; it is not even certain whether or not they represent annual rings. The measurements noted above for the Ohguri plantation, Sibsagar, show an average girth of 2 ft. in twenty-four years, representing a mean annual girth increment of 1 in., which is by no means slow. The tree, however, does not produce a very long straight bole, so that the out-turn development is probably less than the increase in girth might indicate. In the Nambor forest, Sibsagar, it was found that trees 6 ft. in girth yielded on an average 18 metre-gauge sleepers.

In his working plan for the Nambor forest Mr. Dicks quotes a further instance of a small group of *nahor* trees surrounded by other trees behind the circuit-house at Sibsagar. These trees are said to have been planted in 1858-60, and had an average girth of 4 ft. 2 in. when forty-eight years old. No accurate data are available for older trees. There is, however, a general tradition, supported by the presence of temples and tanks, that the Nambor forest was under cultivation prior to the Burmese invasion at the beginning of last century, and that the land relapsed into jungle when the local population was driven out. At the commencement of the present century there were a fair number of *nahor* trees 7 to 8 ft. in girth, but very few above 8 ft. If this tradition be correct, it may thus be assumed that it takes 100 years to produce an average girth of 7½ ft. The following provisional data are thus available:

Age in years.	Girth. ft. in.
24	2 0
48	4 2
100	7 6

Making allowance for possible errors, Mr. Dicks makes the following rough estimate of the rate of growth, based on the above data:

Girth at breast height. ft. in.	Age.
1 6	20
3 0	40
4 6	60
6 0	90

These figures must be considered as purely tentative.

ORDER VIII. TERNSTROEMIACEAE

This order, important mainly as being the one to which the tea-plant belongs, contains several trees of local interest, chiefly hill species. The only one of special importance is *Schima Wallichii*, Choisy.

SCHIMA, Reinw.

Schima Wallichii, Choisy. Syn. *Gordonia integrifolia*, Roxb. Vern. *Chilauni*, Nep., Sikkim, Duars; *Mukria sál*, Ass.; *Laukya*, Burm.

A large handsome evergreen tree, attaining a height of 80–100 ft. and a girth of 10 ft. or more, with a tall straight bole and a dense rounded crown. Bark dark grey with deep vertical fissures. Wood used for building and other purposes, but apt to warp and split. An important tree in the outer hills of the eastern Himalaya and in the Duars.

DISTRIBUTION AND HABITAT. The eastern Himalaya and sub-Himalayan tract from Nepal eastwards, Assam, Khasi hills, Manipur, hills of Chittagong and of Upper Burma. It is often more or less gregarious. In the eastern Himalaya it ascends to about 5,000 ft. or slightly higher, and extends outside the base of the hills for some miles. In the Duars it is common in places mixed with sal on deep rich soil, extending for several miles from the base of the hills down to an elevation of about 1,000 ft. Here both species attain very fine dimensions: it is noticeable, indeed, that *Schima* in this tract is a particularly good indicator of very fine quality of sal forest. Here the rainfall varies from about 120 to 160 in. The tree is abundant in the foot-hills, where it is sometimes the prevailing species, and reaches large dimensions; towards its upper limit it tends to become stunted. It is common in various forest tracts in Assam, where it is sometimes gregarious and reaches a large size. Mr. Jacob¹ states that it is the most common tree in the outer hills in western Bhutan up to 4,000 ft., but is less common in eastern Bhutan. In the hills of Upper Burma it is not found below 3,000 ft., and occurs associated with oaks and other extra-tropical trees: it is common on the Maymyo plateau.

In its natural habitat the absolute maximum shade temperature ordinarily varies from 90° to 100° F., the absolute minimum from 30° to 40° F., and the normal rainfall from 55 to 200 in.

FLOWERING AND FRUITING. The fragrant showy white flowers appear from April to June. The fruit appears to ripen at different seasons according to locality and elevation. Gamble (Darjeeling list) says November–December: Brandis says cold season: Copeland (Manual of Arboriculture for Burma) says April. In the Duars (elevation 1,000 ft.) I have collected ripe capsules, which were dehiscing and shedding their seed, at the end of January and during February. The capsules are hard, woody, globose, five-valved, 0.5–0.7 in. in diameter. The seed is flat, pale greyish brown, with a papery wing extending round about three-quarters of the periphery, 0.35–0.5 in. by 0.2–0.3 in. including the wing, the whole reniform in outline. The seeds are light

¹ Report on the Forests of Bhutan, 1912.

and are spread by the wind: parrots eat them on the trees and break off the capsules, which fall in quantities to the ground. The seed can be extracted from the woody capsules by collecting the latter immediately before opening and placing them in the sun for a few days, when they open and the seed is easily shaken out. Seed-years appear to be common: records for four successive years in the Tista division, Bengal, and in the Ruby Mines division, Upper Burma, showed good seeding.

SILVICULTURAL CHARACTERS. The tree is a moderate light-demander; it regenerates abundantly where sufficient light is admitted for the development of the seedlings, which are sometimes found in great profusion. It coppices well.

ORDER IX. DIPTEROCARPACEAE

This order, which contains 325 known species of trees (rarely shrubs) in 16 genera, is confined to the Indo-Malayan region. So far as richness in species is concerned, India and Burma cannot compare with the Malay Archipelago, but in our region the silvicultural and economic importance of this order is very great, partly because it contains several valuable timber trees and partly because some of these are gregarious in character, simplifying scientific working and cheapening the cost of felling and extraction. Most species are rich in resin or wood-oil, while a valuable form of camphor is yielded by the camphor tree of Borneo (*Dryobalanops aromatica*, Gaertn. f.), which, however, does not occur in our region. Most of the dipterocarps are characterized by tall straight cylindrical boles without branches for a considerable distance from the ground. This characteristic is particularly well marked in the larger species of *Dipterocarpus* and *Hopea*, whose crowns, elevated on long clean stems, tower above the surrounding forest.

LEAF-SHEDDING, FLOWERING, AND FRUITING. Some of the dipterocarps are wholly evergreen, particularly the large species of *Dipterocarpus* and *Hopea* found in tropical evergreen forests. The others are chiefly near the border-line between evergreen and deciduous, approaching the former state in moist fertile localities and the latter in poor dry situations, while certain of these become wholly deciduous in dry regions. As a rule the leaves are shed towards the end of the cold season or early in the hot season, and in the majority of cases flowering takes place during or at the end of the period of leaf-fall; in *Dipterocarpus obtusifolius* the flowers appear before the leaves commence falling. The flowers of the dipterocarps are adapted for insect pollination, some being scented, some large and showy as in *Dipterocarpus*, while in some species they are produced in large quantities when the trees are out of leaf. The majority of the dipterocarps are easily recognized from the fact that 2 or more of the 5 calyx lobes become enlarged in the fruit into wings: there are 2 such wings in *Dipterocarpus* and *Hopea*, 3 or more in *Pentacme* and *Shorea*, and 5 in *Parashorea*. In the great majority of cases the fruits fall towards the end of the hot season or at the commencement of the rainy season, and germinate almost at once. Except possibly in the case of those species which occur in moist tropical forest, in which the fruits fall on damp ground protected from the sun, an essential condition for the germination of the seed is the

occurrence of timely rain, failing which the whole seed-crop may come to nothing. Seed is ordinarily produced to some extent every year, while good seed-years occur at frequent intervals, and in the majority of species the trees are laden with winged fruits, which in the case of the lighter-fruited species are carried to a considerable distance by the strong winds which occur in many localities towards the end of the hot season. The fruits are not in any way protected against damage by fire, but such protection is not required, since they fall mainly after the season of forest fires. A good seed-year followed by timely rain results in an abundant crop of seedlings. The fruits of most if not all species are buoyant in water, and this no doubt aids their spread in the case of those which grow in moist localities near streams.

Germination may be either hypogeous, as in the case of the larger and heavier fruits (*Dipterocarpus*, *Shorea*), or epigeous, as in *Hopea*, the cotyledons escaping from the fruit and being carried above ground.

The following list, giving the flowering and fruiting seasons of the chief dipterocarps in the Indo-Burman region, illustrates the remarkable similarity between the fruiting seasons of the various species and their coincidence with the commencement of the rainy season :

	Flowering.	Fruiting.
<i>Dipterocarpus turbinatus</i> , Gaertn. f.	March–April	May–June (Burma and Assam).
<i>D. alatus</i> , Roxb.	February–March	May–June.
<i>D. indicus</i> , Bedd.	December–January	{ May–July (Coorg). April–May (Travancore, Bourdillon).
<i>D. Bourdillonii</i> , Brandis	January–February	May–June.
<i>D. pilosus</i> , Roxb.	?	{ April (Brandis). February–March (Assam, Kanjilal).
<i>D. Griffithii</i> , Miq.	?	May (Kurz).
<i>D. tuberculatus</i> , Roxb.	March–April	May.
<i>D. costatus</i> , Gaertn. f.	March	April–May.
<i>D. obtusifolius</i> , Teysm.	{ November–January March–April	{ March–April (Siam, Ryan and Kerr). April–May (Burma, Kurz).
<i>Hopea odorata</i> , Roxb.	March–April	May–June.
<i>H. parviflora</i> , Bedd.	January–February	May–June (Bourdillon).
<i>H. Wightiana</i> , Wall.	March–April	May–June.
<i>H. glabra</i> , W. and A. (<i>H. Wightiana</i> var. <i>glabra</i> , Bedd.)	January–February	June–July.
<i>H. racophloea</i> , Dyer	April–May	June–July.
<i>Pentacme suavis</i> , A. DC.	March	May–June.
<i>Shorea robusta</i> , Gaertn. f.	March–April	June.
<i>S. obtusa</i> , Wall.	March	May.
<i>S. Tumbuggaia</i> , Roxb.	March–April	June–July.
<i>S. Talura</i> , Roxb.	February–March	April–May.
<i>S. assamica</i> , Dyer	September	January–February (Assam).
<i>Parashorea stellata</i> , Kurz	March–April (Brandis)	April–May (Kurz).
<i>Balanocarpus utilis</i> , Bedd.	May	Rainy season.
<i>Vatica Roxburghiana</i> , Blume	February–March	June.
<i>Vateria indica</i> , Linn.	January–March	May–July.

In all species which have been studied to any extent the maximum growth takes place for about a month or two after the new leaves appear, that is, in

the hot season. In some cases growth continues to a small extent during the rains, particularly in young trees and coppice-shoots, but in others it ceases entirely before the end of the hot season.

HYGROPHILOUS AND XEROPHILOUS TYPES. The dipterocarps of the Indo-Burman region may be divided into two broad types: (1) the hygrophilous or sporadic type, the species of which occur on fertile ground in moist tropical usually evergreen forest, and (2) the xerophilous or gregarious type, in which the species are adapted to grow in dry or moderately dry localities and to endure conditions under which species of the hygrophilous type would succumb. The terms 'hygrophilous' and 'xerophilous' are here used in a purely relative sense. Strictly speaking it would be more correct to say that dipterocarps in general are mesophytic, but are divisible into two main types, of which one has more xerophilous characteristics than the other: the line of distinction between the two types, however, is sufficiently well marked to warrant the adoption of two terms conveying the idea of contrast.

1. *The hygrophilous type.* This type comprises the largest of the dipterocarps, for example *Dipterocarpus turbinatus*, *D. indicus*, *D. alatus*, *D. pilosus*, *D. Griffithii*, all species of *Hopea* and *Balanocarpus*, *Parashorea stellata*, and *Vateria indica*. *Shorea assamica* and *S. Talura* may also be placed in this type. The trees of this type grow on damp rich soil in tropical moist or evergreen forest, and are themselves typically evergreen. They occur sporadically, and though at times they form pure groups or patches of varying extent, they are not gregarious over large areas. This sporadic growth is due to the fact that there are a large number of other species competing for the ground and thus creating conditions adverse to gregarious growth: outside our region some of the species of this type are said to grow gregariously. The trees are shade-bearing, at all events in youth; their existence depends on this character, as the forest in which they occur is usually dense. As a rule the bark is comparatively thin and smooth, not thick, rough, and deeply fissured. The trees are thus ill-adapted to withstand damage by fire, to which, however, they are not ordinarily subjected in the evergreen forests in which they grow: saplings which are burnt down have poor power of recovery, and unless only slightly scorched are usually killed outright. As far as is known most of the trees coppice badly or not at all: Beddome, however, says that *Hopea Wightiana*, var. *glabra*, coppices well. The forests in which trees of this type occur are not characterized by the presence of numerous forest grasses, but as a rule by a dense evergreen undergrowth.

2. *The xerophilous type.* This type includes *Dipterocarpus tuberculatus*, *D. obtusifolius*, *Pentacme suavis*, and most species of *Shorea*, though *S. assamica* and *S. Talura* belong rather to the hygrophilous type. Although at times sporadic, the trees often grow gregariously over areas of varying extent; this gregarious condition is due not only to the fact that seed is produced in large quantities, but even more to the fact that the conditions under which they grow are less unfavourable to them than to the majority of the species with which they are associated, and the struggle for existence against other species is less severe than in the hygrophilous type. Although they extend into regions of heavy rainfall, the species of this type cannot establish themselves in moist evergreen forest, but cling to localities with drier types of soil and

subsoil; here, however, they become dominant and gregarious, since they are specially adapted to resist the dangers usually prevalent in comparatively dry situations, and can survive these dangers to a greater degree than the majority of their associates. The trees of this type are either deciduous or approach the deciduous state; in dry hot situations they may become entirely deciduous, *Pentacme suavis*, for example, remaining leafless for a month or more in such places, whereas in moister and more fertile localities it does not as a rule become quite leafless. In this respect adaptation to environment is strongly marked. The trees are characterized by thick, rough, often deeply furrowed bark. They are light-demanders or tend towards light-demanding rather than towards shade-bearing habits: thus young growth tends to establish itself in even-aged patches in gaps where sufficient light is admitted. The localities in which the crops establish themselves are characterized not by a dense evergreen undergrowth but by the presence of various forest grasses, which are of great importance to the economy of the crop. These grasses often form extensive savannah tracts within the forests, into which, if these tracts are well drained, the trees gradually spread. The presence of so much grass within the forest is the cause of severe fires, but the dipterocarps in these tracts are specially adapted to resist the effects of fire, not only by reason of their thick bark, but also owing to their great power of recovery from injury: seedlings and saplings may be burnt down year after year, but continue to develop a strong woody growth underground, and eventually establish themselves in spite of fire. Up to a moderate size the species of this type coppice well.

Among adaptations for overcoming adverse conditions, one of the most noteworthy is that exhibited by the sal (*Shorea robusta*) in the annual 'dying back' of seedlings, a phenomenon which may be observed in the case of various species of Indian trees growing in dry regions. Under optimum conditions of soil and moisture the sal, if not exposed to injury by frost, fire, or other agencies, does not die back but shoots straight up from the seed. In the majority of cases, however, where conditions fall short of the optimum by reason of unfavourable climatic or soil factors—for example, deficiency of soil-moisture or bad soil-aeration due to excess of moisture, hardening of the soil, or other causes—the seedlings die back annually for several successive years, during which a strong root-system is developed underground until the seedling is strong enough to shoot up without further dying back. The other dipterocarps of this type have not yet been studied sufficiently to ascertain if the same phenomenon occurs in other species, but it is probable that it does occur in at least some of them in localities where conditions fall short of the optimum. Again, apart from the thick rough bark, the strongly developed root-system, and the capacity for recovery after dying back, several of the species exhibit other xerophytic adaptations against excessive heat and drought or protective devices against intense light, which is a correlated factor. Thus *Dipterocarpus tuberculatus* and *D. obtusifolius* have large sheathing stipules enclosing the buds, while the latter species possesses the capacity for storing quantities of water in its tissues during the dry season. *D. tuberculatus* trees in dry exposed situations tend to hang their leaves more or less vertically, while the leaves of *D. obtusifolius* are deeply folded between the lateral veins;

in either case the direct rays of the midday sun are warded off and excessive transpiration is minimized. The young leaves of several species, notably *Dipterocarpus tuberculatus*, *Pentacme suavis*, and *Shorea robusta*, are red or copper-coloured, while in *Pentacme suavis*, perhaps the most xerophilous of all the dipterocarps, even the older leaves often have a characteristically red colour; this coloration is a well-known protective device against intense light. Ryan and Kerr¹ point out that in the case of *Dipterocarpus tuberculatus*, *D. obtusifolius*, and *Pentacme suavis* there are two well-marked varieties, one in which the young shoots and stipules are glabrous, and the other in which they are tomentose, and that in the case of *Pentacme* the tomentose form is characteristic of dry rocky situations and the glabrous form of more fertile ground; this differentiation of localities has not yet been established in the case of the other two species.

It will thus be seen that the broad silvicultural characters of the two types are well defined. Actually the species of either type may overlap where the respective localities meet, and it is noteworthy that trees of the xerophilous type reach their best development in localities approaching in character those occupied by species of the hygrophilous type. Thus in Burma, where the dry so-called *indaing* forest meets the moist or evergreen forest, the hygrophilous trees *Dipterocarpus turbinatus* and *D. alatus* are occasionally found mixed with the xerophilous species *D. tuberculatus*, *Pentacme suavis*, and *Shorea obtusa*; here the three latter species reach very large dimensions. Again, *Shorea robusta* shows exceptionally fine development in the moist Duars tract of Bengal and Assam, where the rainfall varies from about 130 to 180 in. The tree is here in its optimum habitat, for seedlings raised from seed sown in the open do not die back but shoot rapidly upwards. There is clear evidence that the sal forests of this tract established themselves by degrees in savannah lands which were regularly burnt. Continued fire-protection for thirty to forty years, however, has entirely altered the character of the forests, introducing a previously non-existent evergreen undergrowth, increasing the soil-moisture, and decreasing the soil-aeration: in consequence of this, although the previously established crop continues to flourish, the trees seed freely and the seed germinates well, new regeneration under the altered conditions is entirely unable to establish itself, and the only possible means of regenerating the forests, which are now for the most part too damp to burn, is to clear-fell, burn the dry refuse, cultivate the soil, and regenerate artificially. The case of the Duars forests is an instructive example of the manner in which the sal, like other dipterocarps of the xerophilous type, profits by adverse conditions, to establish itself gregariously where the majority of species fail to obtain a footing, and where these conditions are radically altered, ostensibly for the better, it may lead to the extermination of the once dominant species. An alteration of conditions to this extent would naturally not be possible in drier localities: it is only the moister types of xerophilous dipterocarp forest that are, so to speak, in unstable equilibrium.

STUDY OF SILVICULTURAL CHARACTERS. The general silvicultural characters of this order have been gone into at some length because the majority of the individual species have not yet received sufficient detailed study. As

¹ Journ. Siam Soc., viii (1).

far as we know, however, the silvicultural affinities between the various species of the two main types of dipterocarps are strong, and the facts of which we are in possession regarding certain species may well form a starting-point for the more detailed study of other species of the same type. So far the sal has been studied in much greater detail than any other dipterocarp, and the particulars given below for this species should indicate to some extent the lines of study and methods of treatment for other species of the xerophilous type. Among further characters which experiments or observations have so far shown to be common to both types may be mentioned (1) the adverse effect of a thick layer of dead leaves on the establishment of seedlings and the advantage of burning the soil-covering in order to obtain regeneration;^{1 2} (2) the advantage of fire-protection to aid the establishment of seedlings and the absolute necessity for it in the hygrophilous type;² (3) the advantage of light as an aid to the development of saplings even in the hygrophilous type, and more so in the xerophilous type; (4) the absence of root-suckers as a means of reproduction: if these occur at all they are quite exceptional.

Genera 1. DIPTEROCARPUS, Gaertn. f.; 2. HOPEA, Roxb.; 3. PENTACME, A. DC.; 4. SHOREA, Roxb.; 5. PARASHOREA, Kurz; 6. BALANOCARPUS, Bedd.; 7. VATERIA, Linn.

1. DIPTEROCARPUS, Gaertn. f.

Large, in some cases lofty, trees with straight cylindrical stems. Of the five calyx segments two develop into large wings in the fruit. This genus comprises species both of the hygrophilous and of the xerophilous types: to the former belong Nos. 1, 2, 4, and 6, and to the latter Nos. 3 and 5 of the species dealt with here.

Species 1. *D. turbinatus*, Gaertn. f.; 2. *D. indicus*, Bedd.; 3. *D. obtusifolius*, Teysm.; 4. *D. pilosus*, Roxb.; 5. *D. tuberculatus*, Roxb.; 6. *D. alatus*, Roxb.

1. *Dipterocarpus turbinatus*, Gaertn. f. Syn. *D. laevis*, Ham. Gurjun, wood-oil tree. Vern. *Gurjun*, Beng.; *Kanyin*, *kanyin-ni*, Burm. In the Andamans the name gurjun is applied indiscriminately to more than one species, namely, *D. turbinatus*, *D. Griffithii*, *D. alatus*, and probably one or two others.

A lofty evergreen tree, attaining a height of 150 ft. or more, and a girth of 15 ft. or over, with a long clean cylindrical bole and an elevated crown. Bark light grey, yellowish brown inside, exfoliating in irregular rounded flakes. Locally the wood is used mainly for boat-building, dug-out canoes, and planking; there is an export trade in it from the Andamans, and it has been well reported on in the London market. The tree is tapped for wood-oil.

DISTRIBUTION AND HABITAT. The Andamans, Cachar, Tipperah, Chittagong hills, and throughout the greater part of Burma, extending into Siam. The tree is not typically gregarious over large stretches of country like *D. tuberculatus*, though sometimes it approaches that condition in patches. It is found

¹ Vide experiments described under *Shorea robusta*, pp. 95, 96.

² Vide observations on natural reproduction and silvicultural treatment of *Dipterocarpus turbinatus*, p. 36.

in forests of the moister tropical type, evergreen or semi-evergreen, where along with a few other lofty species it towers above the rest of the forest. In Burma it is associated with *Dipterocarpus alatus*, *Mangifera* spp., *Eugenia* spp., *Lagerstroemia* spp., *Amoora*, *Sterculia alata*, *Garcinia* spp., *Hopea odorata* (in moister localities), *Artocarpus Chaplasha*, *A. Lakoocha*, *Pentace burmanica*, and others, often with an undergrowth of various palms and canes.

In the Andamans it is found in evergreen forest, associated with other dipterocarps, including *D. Griffithii*, *D. alatus*, and *Hopea odorata*, also with *Artocarpus Chaplasha*, *A. Gomeziana*, *Calophyllum spectabile*, *Mimusops Elengi*, *Terminalia bialata*, *Myristica Irya*, and other trees, with a dense undergrowth of canes, climbers, and the climbing bamboo *Dinochloa andamanica*.

In its natural habitat the absolute maximum shade temperature varies from 98° to 105° F., and the absolute minimum from 45° to 60° F., the rainfall varying from 60 to over 200 in.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The old leaves are shed early in the hot season. The rose-coloured flowers appear in March–April, and the fruit ripens in May or early June (Upper Burma), germination taking place as soon as the seed falls.

SILVICULTURAL CHARACTERS. The main silvicultural characters are those of the hygrophilous type of dipterocarps (see p. 32). Notes recorded by Mr. H. R. Blanford¹ show that the tree is very sensitive to fire. In Upper Burma an area where the *tin* bamboo (*Cephalostachyum pergracile*) had flowered gregariously was burnt in 1914, after several years of fire-protection, in order to stimulate the natural regeneration of teak. In this area nearly all the young *kanyin* (*D. turbinatus*) trees up to about 10 ft. in height were killed by the fire: further observations showed similar results in other localities, saplings escaping partially only where the fire had not been fierce. The power of recovery from injury by fire is likewise poor: where a sapling is only slightly scorched it recovers, but if badly damaged it has no power of recovery from the base, as in the case of *D. tuberculatus* and other fire-resisting species. So far as is known the tree neither coppices nor produces root-suckers.

NATURAL REPRODUCTION. In Mr. Blanford's observations mentioned above it was noticed that on areas burnt after several years of fire-protection *kanyin* seedlings appeared in quantity wherever there was sufficient light for their development. There was also a great abundance of *kanyin* saplings on areas fire-protected for some years, and from their size it was concluded that they first appeared when the area was brought under fire-protection. These observations indicate that a burnt area forms an excellent germinating bed for the seed of *kanyin*, as of many other species, but that strict fire-protection is necessary if the seedlings are to establish themselves. The fruits fall after the season of fires, and in the first year the seedlings are therefore not exposed to damage from this source.

In the Andamans Mr. C. G. Rogers² notes that seedlings of several dipterocarps are generally found in the evergreen forests, but it is doubtful if they are able to make their way through the dense growth of climbing bamboo and creepers; he adds that the low density of sound mature trees

¹ Ind. Forester, xli (1915), p. 78.

² Report on the Exploration of the Forests in the South Andaman and other Islands, 1906.

(averaging about one per acre) seems to indicate that only a very small proportion of the seedlings which come up ever succeed in forcing their way through the dense undergrowth and reach maturity.

SILVICULTURAL TREATMENT. Mr. Blanford's observations indicate that the treatment to be adopted to secure natural reproduction of this and other similar dipterocarps of moist regions is to execute a heavy clearing of all cover, retaining sufficient seed-bearers, and to burn the area thoroughly next season, thereafter enforcing strict protection from fire and carrying out the necessary cleanings and thinnings.

2. *Dipterocarpus indicus*, Bedd. Vern. *Challane*, Kan.; *Kalpaini*, Coorg; *Ennei*, Tam.

A lofty evergreen tree attaining a height of 120 ft. or more and a girth of 12 ft. or over, with a tall clean cylindrical bole. Bark light grey, smooth. Wood reddish grey, somewhat rough, not very durable, used for interior construction not in contact with the ground. The tree is tapped for wood-oil. This species strongly resembles *D. turbinatus*.

DISTRIBUTION AND HABITAT. The Western Ghats from North Kanara southwards to Travancore, in evergreen forests up to 3,000 ft. The climate of this region is a humid one: the absolute maximum shade temperature varies from 95° to 100° F., the absolute minimum from 55° to 65° F., and the normal rainfall from about 80 to 200 in. or more.

FLOWERING AND FRUITING. The fragrant white flowers appear in December-January, and the fruit ripens from April to early July, according to locality. The fruit (Fig. 10, *a*) is large and somewhat heavy, with two wings about 4 in. long.

GERMINATION (Fig. 10, *b*, *c*). Hypogeous. The radicle emerges from between the wings and curves rapidly downwards, the cotyledonary petioles meanwhile elongating to a length of about an inch, enabling the plumule to emerge from between them. The thick fleshy cotyledons remain within the fruit.

THE SEEDLING (Fig. 10).

Roots: primary root long, thick, terete, tapering, woody: lateral roots few, short, fibrous, distributed down main root. *Hypocotyl* scarcely distinguishable. *Cotyledons* subterranean: petiole 1-1.5 in. long: lamina about 1 in. long, thick, fleshy, obovate, the two conferruminate within the fruit, forming an obovoid fleshy mass. *Stem* erect, terete, woody, densely tomentose with stellate hairs, especially in the younger parts; internodes, the first (between cotyledons and first foliage leaves) 4-8 in., subsequent internodes 0.3-1 in. long. *Leaves* simple, first pair opposite, subsequent leaves alternate. *Stipules* 0.4-0.5 in. long, ligulate, tomentose, caducous. *Petiole* 0.4-0.8 in. long, stellate tomentose. *Lamina* 2-6 in. by 1.5-2.7 in., elliptical ovate, entire, acuminate, base rounded, upper surface glabrous, lower stellate tomentose on the principal veins, margins ciliate; lateral veins prominent, 8-12 pairs.

Seedlings 3½ years old raised from sowings under moderate shade in abandoned clearings in Coorg attained an average and maximum height of 3 ft. and 4 ft. 7 in. respectively. The seedling is sensitive to drought.

SILVICULTURAL CHARACTERS. This species belongs to the hygrophilous type of dipterocarps (see p. 32), and its silvicultural characters and conditions of reproduction are somewhat similar to those of *D. turbinatus*.

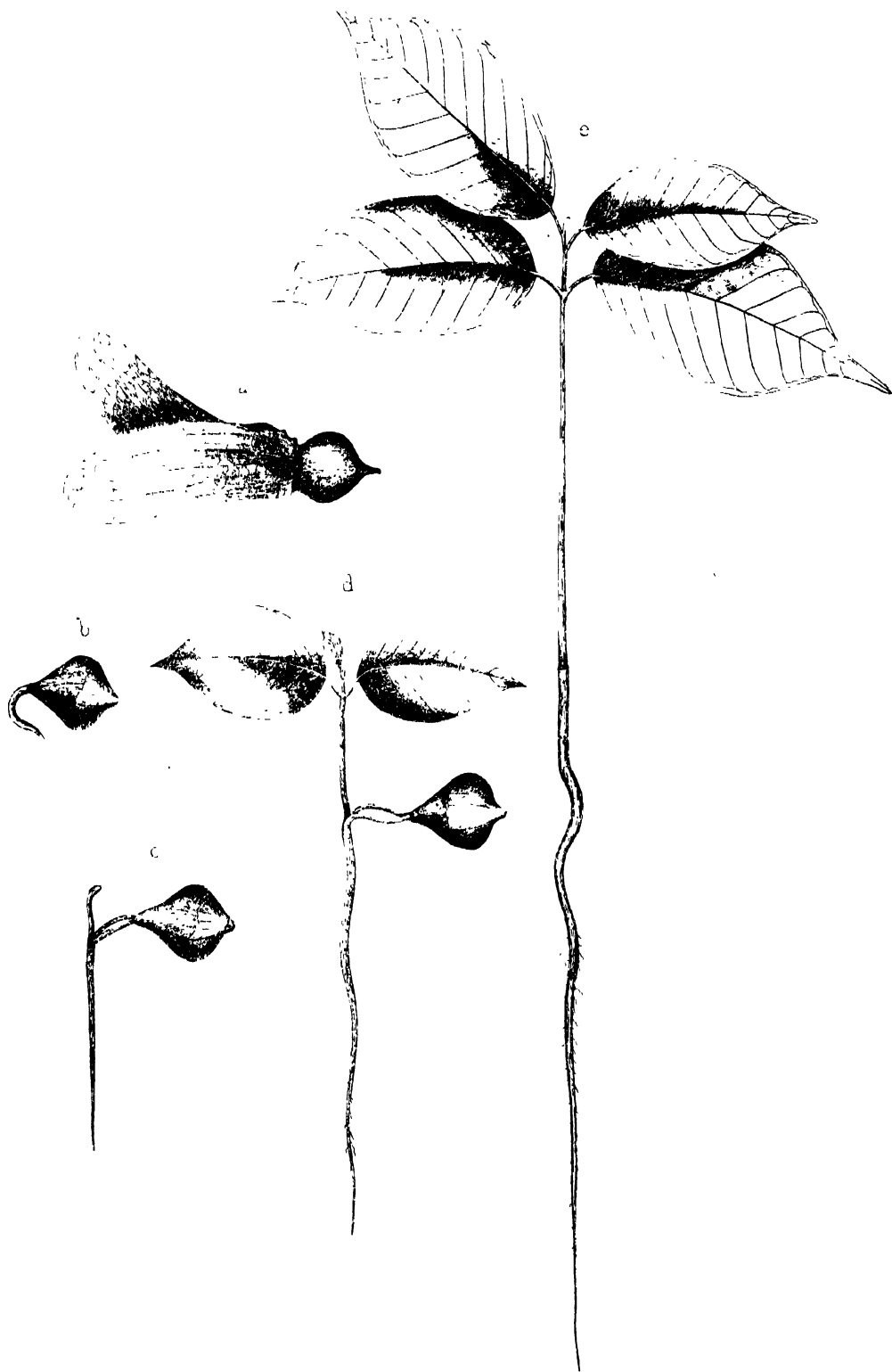


FIG. 10. *Dipterocarpus indicus* (West India). Seedling $\times \frac{3}{8}$.

a, fruit ; b, c, germination stages (wings removed from fruit) ; d, seedling one month old ; e, seedling towards end of first season.

3. *Dipterocarpus obtusifolius*, Teysm. Vern. *Inbo*, *kanyingôk*, Burm. (Specimens of *inbo* or *kanyingôk* from Thaungyin have been identified as *D. tuberculatus* var. *grandiflorus*).

A large deciduous tree up to 80 ft. high; bark rough, grey, reddish brown inside, longitudinally fissured and slightly transversely cracked. The bole is usually clean, the branches spreading more or less umbrella-like above.

DISTRIBUTION AND HABITAT. Burma, common in the hills east of the Sittang, and in the *indaing* forests of the Prome District (Kurz). Common in Cochin China, Cambodia, and Siam. The tree has habits somewhat similar to those of *D. tuberculatus*, growing gregariously in dry forest which may be termed 'hill *indaing*', up to 3,000 ft. elevation. This forest occurs mainly on laterite or on sandy or gravelly soil overlying metamorphic formations. Here *Dipterocarpus obtusifolius* is associated with various oaks, *Engelhardtia Colebrookiana*, *Schima bancana*, *Castanopsis tribuloides*, *Dillenia aurea*, and occasionally with certain trees of the ordinary *indaing* forest, such as *Dipterocarpus tuberculatus*, *Shorea obtusa*, *Pentacme suavis*, *Melanorrhoea usitata*, and others. *Pinus Merkusii* is sometimes found in this type of forest, while towards its upper limit *P. Khasya* makes its appearance. In this forest there is usually a characteristic growth of grass, rendering it inflammable and liable to fierce fires. Ryan and Kerr,¹ writing of the occurrence of the tree in Siam, say that it commonly forms forests in two situations, on the plain where the soil is sandy, and on steep slopes and crests of ridges at 2,000–3,000 ft. elevation: on the hills this forest is usually on red clay, and *D. obtusifolius* forms about 50–60 per cent. of the crop, most of the other trees being oaks, with occasional *Shorea obtusa* and *Pentacme suavis*.

LEAF-SHEDDING, FLOWERING, AND FRUITING. According to Ryan and Kerr the tree in Siam flowers from November to January, the leaves falling a little later, and the fruit ripens in March–April: the wings are 4–6 in. long. Kurz says the flowering season is March–April and the fruit ripens April–May (Burma). The fruits are heavy, and are probably not carried very far from the tree in spite of the fact that there are fairly strong breezes towards the end of the hot season when they ripen.

SILVICULTURAL CHARACTERS. The tree has the general silvicultural characters of the xerophilous type of dipterocarps (see p. 32). It is adapted by its thick rough bark to withstand the annual fires; the seedlings are burnt back, but a certain proportion eventually establish themselves. As remarked by Ryan and Kerr, an adaptation for withstanding drought in the dry habitat of this species is its capacity for storing water in its tissues: a characteristic of the young tree is that when cut it exudes a quantity of water which drops out freely when the cut stem is held upside down. The tree coppices well, but does not produce root-suckers. It is a light-demander, and regeneration sometimes springs up freely in abandoned *taungyas*.

4. *Dipterocarpus pilosus*, Roxb. Syn. *D. Baudii*, Korth. Vern. *Hollong*, Ass.

A large evergreen tree reaching a height of 100 ft. and exceptionally 120 ft., with a long clean bole. Trees up to 23 ft. in girth have been recorded.

DISTRIBUTION AND HABITAT. Upper Assam, Chittagong, Arakan, and

¹ loc. cit.

Tenasserim, and the hills east of the Sittang in Burma : found also in Sumatra and the Philippines. It is found in moist evergreen forests, and though very common in places, particularly in Assam, it can hardly be called a gregarious tree in India or Burma. In Sumatra and the Philippines it is said to be gregarious. It grows on moist well-drained ground, both on flat land and on low hills. In its natural habitat the absolute maximum shade temperature varies from 98° to 102° F., the absolute minimum from 40° to 50° F., and the normal rainfall from 90 to over 200 in.

FRUITING. In Assam the fruits, which are heavy, with wings 7–9 in. long, ripen in February and March, after which there is usually much wet weather until the rainy season commences.

SILVICULTURAL CHARACTERS. The main silvicultural characters are those of the hygrophilous type of dipterocarps (see p. 32), but these characters have not yet been studied in detail for this species. Fires seldom if ever occur in the type of forest in which it is found. Mr. Kanjilal informs me that in Assam natural reproduction is profuse where the rainfall approaches or exceeds 100 in. He also notes that seedlings endure shade until they reach the sapling stage ; from then onwards an increasing amount of light is required, and mature trees have their heads well above the surrounding leaf-canopy.

5. *Dipterocarpus tuberculatus*, Roxb. Syn. *D. grandiflorus*, Wall. Vern. *In*, Burm. ; usually known in English as ‘ eng ’. Specimens of *inbo* or *kanyin-gôk* from Thaungyin have been identified as *Dipterocarpus tuberculatus*, Roxb., var. *grandiflorus*.

A large resinous tree, deciduous or nearly so, with a straight clean cylindrical bole and stout branches. Bark dark grey, brown inside, thick, rough, and longitudinally furrowed. Wood reddish brown, hard, moderately durable, largely used in Burma for building and occasionally exported to Europe. In favourable localities the tree attains a height of 80 to 100 ft., with a clear bole of 50 to 60 ft. and a girth of 8 to 10 ft. ; exceptionally it may attain a height of 120 ft. or more and a girth of 15 ft. The following measurements of large trees have actually been recorded :

- | | | | | |
|-----|------------------|---------------------|---------------|------------------------------------|
| (1) | Height 120 ft. : | clear bole 54 ft. : | girth 12 ft. | (F. J. Branthwaite,
Toungoo). # |
| (2) | „ 100 ft. : | | „ 15 ft. | (F. J. Branthwaite,
Toungoo). |
| (3) | „ „ 95½ ft. : | „ 9 ft. 4 in. | | (C. B. Smales, Pyin
mana). |
| (4) | „ 130 ft. : | „ 8 ft. 6 in. | | (R. M. Kavanagh,
Shwebo). |
| (5) | „ 130 ft. : | „ „ 80 ft. : | „ 9 ft. 9 in. | (R. S. Troup, Katha). |
| (6) | „ „ 75 ft. : | „ 11 ft. 1 in. | „ „ „ | |

DISTRIBUTION AND HABITAT. The *in* tree, which grows gregariously in a special type of deciduous forest known as *indaing*, described below, is found throughout Burma, in suitable localities, up to about 2,500 ft. and occasionally over, from the Myitkyina and Upper Chindwin districts in the north to the Mergui district in the south : it occurs in the Northern and Southern Shan States and extends eastward into Cambodia and Siam. The largest tracts of

indaing forest occur between the Irrawaddy and Chindwin rivers in Upper Burma, where they aggregate several thousand square miles. In the Chindwin drainage *indaing* is not common north of Homalin, while west of the river it is less common in the Upper Chindwin district than farther down in the Myittha neighbourhood. East of the upper Irrawaddy there are considerable tracts of *indaing*, varying in size, from the Myitkyina district in the north to the Mandalay district in the south. In the Pegu Yoma *indaing* forest is found to a greater or less extent flanking the outskirts of the teak forests both on the east and on the west side; this type of forest also extends a considerable distance into the hills. *Indaing* is found in the dry zone of Upper Burma, though the trees do not attain large dimensions there. East of the Sittang river a belt of *indaing* runs almost continuously along the base of the hills forming the Sittang-Salween watershed from the Yamethin district southward to some distance below Shwegyin. West of the Irrawaddy below Mandalay it occurs in stretches of varying size from the Pakokku district southward to the Bassein district, ascending the Arakan hills to about 2,500 ft. On the Arakan side the *in* tree is said to be found in the Kyaukpyu subdivision on hill-sides up to 1,200 ft. in groups in evergreen forest with an undergrowth of palms and canes, which is quite unlike its ordinary habit. Its distribution in Chittagong has not been determined. In the lower Salween, Thaungyin, and Ataran drainages *indaing* forest is found scattered in patches of varying extent; these continue southward to the Tavoy and Mergui districts.

In *indaing* forest the *in* tree is usually the most prevalent species and is commonly associated with *Pentacme suavis*, *Shorea obtusa*, *Melanorrhoea usitata*, *Buchanania latifolia*, *Diospyros burmanica*, *Aporosa macrophylla*, *Dillenia pulcherrima*, *Careya arborea*, *Dalbergia cultrata*, *Terminalia tomentosa* var. *macrocarpa*, a stunted form of *Xylia dolabriformis*, and others, while in Upper Burma occur *Dalbergia Oliveri* and certain oaks. Teak of small size is sometimes found scattered in *indaing* forest. Among small trees may be mentioned *Gardenia erythroclada*, *G. coronaria*, *G. sessiliflora*, *G. turgida*, *G. obtusifolia*, *Randia dumetorum*, *Strychnos Nux-blanda*, and *Wendlandia tinctoria*.

Indaing forest varies greatly in quality. It is found most commonly on laterite, often with a red clay soil; here *in* is usually the prevailing tree, reaching a large size in places where the overlying soil becomes a deep sandy loam. *Indaing* forest containing large-sized *in* is also found on almost pure sand. On hard ferruginous laterite with siliceous pebbles, where the soil is shallow, the forest becomes very open and poor in quality. A type of *indaing* occurs on stiff clay soils, but in such places *Terminalia tomentosa* var. *macrocarpa* tends to become the predominating species, and *in* may be entirely absent; this type is exemplified near Teinhmyôk in the Tharrawaddy district and elsewhere. In the plains of the Hanthawaddy district *in* forest tends to merge into lower mixed forest. The best *indaing* forest is found on flat or slightly undulating land, always on porous well-drained soil above the reach of floods. On dry hills and ridges it is frequently stunted and tends to develop into a type containing little or no *in*, but much *ingyin* (*Pentacme suavis*) and *thitya* (*Shorea obtusa*). In the upper mixed teak forests of the Pegu Yoma and elsewhere *in* is often found occupying the tops of ridges, sometimes accompanied by teak of small size. In the Myingyan district on the flat and

undulating land immediately to the east of Popa Mountain there is a patch of forest on volcanic ash consisting of *in* partly pure and partly mixed with teak. In some parts of Upper Burma forest of a somewhat moist type is occasionally found, in which *in* is mixed with *kanyin* (*D. turbinatus*); here the trees reach very large dimensions. In the Chindwin an occasional type is met with on dry sandy loam consisting chiefly of large *in* trees with a lower story of oaks (chiefly *Quercus spicata*). The *indaing* forests of the hill ranges extend into the region of pines (*Pinus Khasya* and *P. Merkusii*), but in these forests the *in* is often replaced by *inbo* (*D. obtusifolius*).

The soil-covering in *indaing* forest varies considerably. In the dry stunted open types with shallow soil there is often little or nothing growing on the bare laterite rock or dry gravel except occasional scanty tufts of grass. The soil-covering in the usual type of *indaing* on more or less level ground often consists of extensive stretches of grass, through which severe fires rage in the dry season (see Fig. 11). The grasses in *indaing* forest are well worth special study in connexion with the silviculture of the tree, as in the case of those of the sal forests of India. There is sometimes a shrubby undergrowth present which increases with the fertility of the soil; this, however, is not of the dense character found in evergreen forest, and usually consists mainly of a rather sparse low growth of *Indigofera*, *Flemingia*, *Desmodium*, *Strobilanthes*, *Inula Cappa* and *polygonata*, *Bauhinia acuminata*, *Thespesia Lampas*, *Barleria cristata* and other shrubs, while *Cycas siamensis* and *Phoenix acaulis* are often very common. Bamboos are usually scarce or absent; where present the most characteristic species are *Dendrocalamus strictus*, *Bambusa Tulda*, and *Oxytenanthera albociliata*: other species also occur at times, but they are less characteristic. Climbers are by no means plentiful, but a feature of these open forests is the number of epiphytic orchids met with. Many herbaceous plants, chiefly perennials with tuberous roots, spring up in the rainy season and flower towards the end of the rains or in the cold season. Most of the trees are leafless during part of the hot season, but many of them flower at this time, and the bright colours and the perfume compensate to some extent for the lack of foliage, while on the ground blackened by the jungle fires, bright-coloured flowers spring up, chiefly those of monocotyledonous plants (Scitamineae and Amaryllidaceae). The orchids flower for the most part in the hot season, adding to the general colour effect: at this season such attractions are by no means without their value in these hot and often waterless tracts, where the woes of the traveller are not lessened by the incessant noise of countless cicadas which choose this time of year to assert themselves, particularly in *indaing* forest.

Indaing furnishes an interesting example of a type of forest the occurrence of which is determined mainly by geological formation, and to some extent by the configuration of the ground as affecting the degree of moisture in the soil. Thus in Burma, as surely as laterite is met with, so surely, with very few exceptions, will this type of forest occupy the ground. Again, this type—in which, however, *in* is often replaced entirely by *Pentacme suavis* and *Shorea obtusa*—frequently occurs along dry ridges, the lower slopes of which are occupied by mixed deciduous or evergreen forest. The component species of *indaing* forest are adapted to withstand a degree of dryness in the soil

which most species in the same climatic region would be incapable of enduring.

As regards climatic requirements, *indaing* forest occurs throughout Burma in localities where the absolute maximum shade temperature varies from 100° to 110° F., the absolute minimum from 40° to 50° F., and the normal rainfall from 35 to 120 in. or possibly more, though the *in* tree itself does not occur except in stunted form where the rainfall is less than 40 in. Although the *in* is characteristically found on dry porous formations, there is a limit to the degree of dryness which it will stand. The most arid portions of the dry zone of Upper Burma are occupied by scrub forests of *Acacia Catechu*, *A. leucophloea*, and other xerophilous species, and where *in* occurs it is not found in the driest regions. A form of poor stunted *indaing*, it is true, occurs in certain portions of the dry zone, but the predominating dipterocarp is usually *Pentacme suavis*, sometimes associated with *Shorea obtusa*; these two species appear to stand a greater degree of dryness than *in*.

The relative proportion of *in* to other *indaing* species varies according to the type of forest; in some types it predominates largely, while in others it is to a great extent, if not entirely, replaced by *Pentacme suavis* and *Shorea obtusa*. Various enumerations have been made in sample plots of *indaing* in which *in* predominates. The maximum number of *in* trees 3 ft. and over in girth recorded is an average of 24 per acre in a sample plot of 86.6 acres in the Gwethe reserve, Toungoo. A few plots containing 20 and over, and many containing 15 and over per acre, have been recorded in sample plots varying from 40 to 200 acres in area. The highest percentage of *in* trees in the growing stock is recorded in a sample plot of 114 acres in the Gwethe reserve, where *in* forms 83 per cent. of the crop of trees 3 ft. and over in girth: it is exceptional to find it constituting more than 70 per cent. of the growing stock.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The large stiff shiny leaves, up to 1½ ft. long, or more in vigorous saplings and coppice-shoots, are shed in the hot season about March, and the new leaves appear at once, or even before the old ones have all fallen, the large stipules, 4-5 in. long, falling as the young leaves expand. The rose-coloured flowers appear in March-April; the fruits, whose wings are 5-6 in. long, ripen in May, and are dispersed by the strong winds which are usually prevalent at this time. Records of seed-years are somewhat scanty, but such as they are they show that occasional poor seed-years occur; otherwise it is known that the tree produces a good crop of seed in most years.

SILVICULTURAL CHARACTERS. The *in* tree is a decided light-demander, as shown by the open character of the forest in which it grows, the readiness with which it responds to openings in the canopy, and its intolerance of suppression. It resists the effects of fire to a remarkable degree, seedlings and saplings which are burnt back showing great power of recovery from the base and sending up stout stems, while the thick rough bark forms an efficient protection to the growing tissues underneath. Its capacity for thriving on porous geological formations and soils which have a low percentage of moisture has already been alluded to. Frost does not occur within its habitat except possibly near its upper limit, where, however, no frost damage has ever been recorded.

Young trees coppice well, but larger trees as a rule fail to coppice. Root-suckers, if they occur at all, are not a usual means of reproduction; Ryan and Kerr state that they have noticed them very occasionally in Siam. As in other dipterocarps, new growth starts in the hot season when the new leaves appear, and most of the season's growth is put on during the first month or two, although growth continues to some extent during the rains.

NATURAL REPRODUCTION. The fruit falls after the season of fires, and is therefore not exposed to the risk of destruction from this source. The seed germinates immediately after it falls, and when the rains break about the middle of May, the seedlings have a favourable start. Lack of rain, however, may cause failure of the seedling crop, particularly in dry localities; thus experimental sowings in the Minbu division in 1907 resulted in failure, the seed germinating successfully but the seedlings nearly all dying for want of rain in June. Given suitable conditions the seedlings come up in enormous quantities, and the profusion with which natural reproduction of *in* takes possession of the ground is one of the remarkable characteristics of this tree: this is well illustrated in Fig. 12. It is only where the crop is sufficiently open that natural reproduction establishes itself in profusion. Many of the more accessible *indaing* forests of Burma, which have been heavily overworked, contain dense crops of poles and saplings, the result of the free admission of light; these are often partly of coppice origin, though seedling reproduction plays a prominent part. The seedlings in their earlier stages are usually burnt back by the annual fires, but thanks to a thick well-developed root, great power of recovery from the base, and a stout stem well protected by rough bark, they eventually establish themselves.

Under certain conditions, however, reproduction fails to establish itself, as in the case of very poor localities where the forest is open and the trees stunted, with bare rock coming to the surface or at most a shallow covering of loose gravelly soil. Here the absence of reproduction is no doubt due partly to the fact that seed is washed away in the rains, or if it remains and germinates the roots cannot obtain a foothold, and partly to the fact that any seedlings which do spring up are killed off by drought, since the root-system cannot develop. Cases of this kind, however, are of little consequence, since even if regeneration were obtained the resulting forest would be so poor as to be of little value. There is, on the other hand, another type of *indaing* where the scarcity or absence of reproduction gives cause for anxiety. This is the type consisting of a rather open crop of *in* trees, often of large size and excellent quality, where the ground is usually covered with a plentiful growth of coarse grasses, with or without shrubs, but where reproduction fails to appear even if there is sufficient light (Fig. 11). The natural reproduction of the *in* tree has not yet been studied in sufficient detail to explain this phenomenon by the results of direct experiment, but the striking similarity which the reproduction of this tree bears in some respects to that of the sal (*Shorea robusta*), which has been studied in greater detail, may furnish a possible explanation of it. Assuming that light conditions are suitable, as they frequently are, a possible cause of failure of reproduction, where a heavy growth of grass is present, is fire; it is known, however, that in many places *in* reproduction



FIG. 11. *Dipterocarpus tuberculatus*, large trees in open forest with soil-covering of coarse grass, Katha, Upper Burma. Note man at base of near tree.





FIG. 13. *Dipterocarpus alatus*, 18 ft. in girth, Magayi reserve, Insein forest division, Burma.

establishes itself in burnt areas in spite of the presence of grass, so that although fire may be a contributory cause it is not the sole, and possibly not even the chief, cause of failure. It is more probable that unfavourable soil conditions, expressed by the term bad soil-aeration, are the primary cause; the remarks on this subject in respect of sal seedlings (pp. 84–86) may help to throw some light on the question. If this is in reality the primary cause, then it may be possible, as in the case of the sal, to stimulate reproduction by hoeing the soil thoroughly and, if necessary, sowing freshly collected seed.

Observations regarding the effect of fire-protection on the regeneration of *indaing* forest have not yet revealed any definite results. The tree regenerates so freely in annually burnt areas that under ordinary conditions expenditure on fire-protection, except possibly during the early stages in the establishment of the young crop, seems hardly justified in the absence of very marked beneficial effects on the establishment of reproduction or the development of the crop. Annual fires do not damage the timber to any extent except in the case of trees tapped for wood-oil, and this custom is not permitted where regulated working is in force.

If the analogy between *in* forest and sal forest holds good, then fire-protection is likely to have an adverse effect on the germination of the seed and the establishment of the seedling owing to the layer of dead leaves on the ground. In the case of the sal it has been proved by experiment that seed falling on a thick layer of dead leaves may entirely fail to germinate if exposed to the sun, while under shelter, although the seed germinates and the seedlings develop during the first rainy season, their roots fail to reach the mineral soil, and the seedlings die off during the ensuing dry weather. If this happens in the case of the sal it may be expected to be even more pronounced in the case of the *in*, whose leaves are much larger and stiffer. In fire-protected *in* forests, therefore, the burning of the accumulated dead leaves in good seed-years, before the fall of the fruits, may be found to be a necessary measure for securing reproduction. An instance of the beneficial effects of burning combined with the admission of light is recorded in the Burma Forest Report for 1914–15: plentiful reproduction is said to have sprung up in the Yetkanzin reserve, North Toungoo, as the result of burning an area in which bamboos had flowered and which had previously been fire-protected for many years.

SILVICULTURAL TREATMENT. *Indaing* forest is well adapted for concentrated regeneration with the view of producing a succession of even-aged crops. This treatment has recently been introduced in Mr. A. P. Davis's working plan for the Indaung working circle.¹ A rotation of 120 years has been adopted tentatively and divided into four regeneration periods of thirty years each. In the first periodic block the number and frequency of the regeneration fellings are not fixed, but a maximum of three fellings is laid down: often only a single final felling will be necessary, since natural reproduction of *in* is plentiful. Blocks not under regeneration will be treated under selection fellings with a minimum girth limit of 8 ft. for sound trees.

RATE OF GROWTH. Accurate figures based on sample plot measurements are not yet available. In the Rangoon Plains working plan (J. J. Rorie) it

¹ Working Plan for the Indaung Working Circle, Ruby Mines Division, 1918.

is estimated from ring-countings that the relative rates of growth in girth of *in* and teak in that locality are as follows :

Girth	1½ ft.	3 ft.	4½ ft.	6 ft.
Age (years) { <i>In</i>	27	52	80	112
{ Teak	43	67	91	125

Ten years were added in either case to allow for the establishment of the seedling.

It is doubtful, however, if great reliance can be placed on ring-countings on *in* stumps, as the rings are not usually clear.

6. *Dipterocarpus alatus*, Roxb. Vern. *Kanyin*, *kanyin-byu*, Burm.; *Gurjun*, Beng. (Andamans).

A lofty evergreen tree, reaching a height of 150–180 ft. and a girth of 15 ft. or more, with a long clean cylindrical bole and an elevated crown. Bark light grey, pale yellow inside, smooth, fairly thin. Fig. 13 shows a tree 18 ft. in girth: Mr. J. J. Rorie has recorded one 22 ft. in girth.

DISTRIBUTION AND HABITAT. Evergreen and moist forests of Burma, Siam, Cambodia, Cocos islands (Prain), and the Andamans. This tree resembles *D. turbinatus* in general appearance and is associated with it in similar types of forest (see under *D. turbinatus*). In Burma these two species are often referred to together as *kanyin*, and as a rule are not carefully distinguished by foresters. Apart from its frequent occurrence in evergreen types of forest, it is probably the species most commonly found on the plains of Burma in the moister types of lower mixed forest, partly evergreen and partly deciduous, on fertile alluvial ground; here it is associated with *Eugenia Jambolana*, *Lagerstroemia Flos-Reginae*, *L. tomentosa*, *L. macrocarpa*, *Stephegyne diversifolia*, *Adina sessilifolia*, *Careya arborea*, *Mangifera indica*, *Berrya Ammonilla*, and others: occasionally teak of large dimensions is found growing with it. In this type of forest the *kanyin* occupies the moister and richer localities on well-drained ground which, however, is sometimes flooded in the rains. In the evergreen and moist semi-evergreen types of forest on flat to undulating ground or low hills flanking the Pegu Yoma range it is extremely common in places. The smooth light grey cylindrical boles, sometimes well over 100 ft. in length without a branch, are very characteristic, and the crowns tower above the surrounding forest.

In its natural habitat the absolute maximum shade temperature varies from 98° to 105° F., and the absolute minimum from 45° to 60° F., the normal rainfall varying from 60 to over 200 in.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The old leaves are shed early in the hot season. The white flowers appear in February–March and the fruits ripen in May–June: the wings are 5–6 in. long.

SILVICULTURAL CHARACTERS. The main silvicultural characters of this tree are those of the hygrophilous type of dipterocarps (see p. 32), and resemble those of *D. turbinatus*.

RATE OF GROWTH. Accurate statistics determining the rate of growth are not yet available. Ring-countings on stumps in the Rangoon plains forests by Mr. J. J. Rorie showed the following relative rates of growth of *kanyin*, *in* (*Dipterocarpus tuberculatus*), and teak:

Girth	1½ ft.	3 ft.	4½ ft.	6 ft.
Age (years) { <i>Kanyin</i>	35	55	79	105
{ <i>In</i>	27	52	80	112
{ <i>Teak</i>	43	67	91	125

Ten years were added in each case to allow for the establishment of the seedling. It is doubtful, however, if great reliance can be placed on the figures for the dipterocarps, as the rings are not always conspicuous.

2. HOPEA, Roxb.

Evergreen trees of the moist tropical forests.

Species 1. *H. odorata*, Roxb.; 2. *H. parviflora*, Bedd.; 3. *H. Wightiana*, Wall.

1. *Hopea odorata*, Roxb. Vern. *Thingan*, Burm.

A large evergreen tree reaching a height of 100–120 ft. and a girth of 12 ft. or more, with a long clean cylindrical bole. Bark grey to dark brown, longitudinally furrowed, yellow or reddish inside. This is the most valuable of the Burmese dipterocarps, having a hard very durable timber much in request for boat-building, canoes, and construction generally.

DISTRIBUTION AND HABITAT. Burma, from Pynmana southwards through Pegu and Tenasserim, and in the Andamans. It extends into Siam and Cochin China. In Burma it occurs sporadically in moist tropical forests, where it is common in Tenasserim and in parts of Pegu, both to the east of the Sittang and in the moister forests of the eastern drainage of the Pegu Yoma, extending northwards into the damper ravines of the Pynmana forests in Upper Burma: on the western side of the Pegu Yoma it extends as far north as the Tharrawaddy district, and though it has occasionally been recorded as far north as the Thayetmyo district, it is extremely rare. Its chief associates are *Dipterocarpus turbinatus* and *alatus*, *Sterculia alata*, *Tetrameles nudiflora*, *Artocarpus Chaplasha* and *Lakoocha*, *Swintonia Schwenckii*, *Garcinia* spp., and other trees characteristic of moist tropical forest: the undergrowth is usually of a dense evergreen character, with various palms and canes and masses of climbers. *Hopea* is found typically on deep rich soil, most commonly along the banks of streams and in damp situations. In the Andamans it is found scattered in moist tropical evergreen forests associated with *Dipterocarpus turbinatus*, *D. Griffithii*, and other species, *Calophyllum spectabile*, *Mimusops Elengi*, *Artocarpus* spp., and many other trees, with a dense undergrowth of the climbing bamboo *Dinochloa andamanica*, various canes, and many climbers.

In its natural habitat the absolute maximum shade temperature varies from 98° to 105° F., and the absolute minimum from 45° to 60° F., the rainfall varying from 90 to over 200 in.

FLOWERING AND FRUITING. The small white fragrant flowers appear in March and April and the fruits ripen in May and June: the latter are small, the two wings being about 1.5 in. long. As in all the dipterocarps, the fruits germinate as soon as they fall.

SILVICULTURAL CHARACTERS. This tree is one of the most hygrophilous of all the dipterocarps, and its general silvicultural characters are those of the

hygrophilous or sporadic type (see p. 32). It stands a considerable amount of shade, particularly in youth.

2. *Hopea parviflora*, Bedd. Vern. *Kongu*, *vellai kongu*, Tam.; *Bovumara*, *kiralboghi*, *tirpu*, Kan.; *Thambagam*, *kambagam*, Mal., Trav.; *Iruppu*, Coorg. Ironwood of Malabar. White kongu (Tinnevelly).

A very large handsome evergreen tree with a dense crown, conical in youth, reaching a height of 120 ft. and a girth of 15 to 18 ft. and exceptionally more, and producing a straight clean cylindrical bole 60 to 80 ft. long. Bark light brown or greyish mottled with white markings, smooth in young trees, somewhat rougher and rusty brown in older ones. Leaves bright green, about 2-4 in. long. The wood is a valuable one, hard, heavy, and durable, used for building and boats. Mr. P. M. Lushington records a case of a large tree felled in the Tinnevelly district which is said to have produced over 200 rafters of nearly 2 cubic ft. each.

DISTRIBUTION AND HABITAT. Coorg, up to 2,500 ft., South Canara, Malabar, Travancore, and Tinnevelly, in moist tropical evergreen forest. Foulkes says that it prefers rich deep moist soil, growing best on river-banks and in moist valleys, but will thrive even on dry hard laterite, which it prefers to gneiss. Mr. P. M. Lushington,¹ writing of the tree in Tinnevelly, says he has seen it in several places growing with or close to *Pterocarpus Marsupium* in the moister parts of the higher deciduous forests, but that more frequently it grows with *Pterospermum* spp., *Vitex altissima*, *Diospyros* spp., and *Filicium decipiens*: he says that there are often patches of nearly pure *Hopea* forest, and that it is a tree which is nearly always found in large patches. In Tinnevelly its area is decidedly limited, but regeneration is said to be good, and there appears to be no likelihood of its diminution. In this district *Hopea parviflora* is known as *Vellai kongu* or white kongu, and *Balanocarpus utilis* as *karin kongu* or black kongu, and on the occurrence of these two trees Mr. Lushington remarks: 'The lowest elevation at which I have found kongu is just below 1,000 ft. . . . and the highest . . . 2,800 ft. The lowest were the black variety and the highest the white: but between these two elevations both kinds are found very commonly growing together. It is essentially a semi-shola tree, and seems to prefer a rich soil, but I have found well-grown saplings growing out of the crevices of slab rock on the banks of the Servi Ar and Kudivarai Ar, and both species seem able to support themselves in such situations. One fact in connexion with kongu has particularly struck me—it is found mainly on the hill-sides bordering on large rivers, and even when a little distance away from the river it is invariably on the bank of a ravine. The close proximity of running water appears to be essential to its growth.'

Bourdillon² says that it is abundant and gregarious in the interior forests of Travancore which have not yet been worked, especially from 1,000 to 2,000 ft.; at lower elevations it is less gregarious, and is found chiefly along river-banks. Writing in the *Indian Forester*,³ he says it is found in most of the evergreen forests between sea-level and 3,000 ft., and at all elevations it is found scattered through the forest, often in groups. 'In the low country', he adds, 'it is generally to be seen on river-sides, but this is because it has

¹ Ind. Forester, xxix (1903), p. 431.

² Forest Trees of Travancore.

³ Ind. Forester, xxx (1904), p. 18.

been cleared away from the adjacent land, for where groves or patches of forest have been left this tree is found in them, even far from water. At the same time it is a tree that likes moisture, for it thrives in swampy patches where other trees would die.'

In its natural habitat the absolute maximum shade temperature varies from 95° to 100° F., the absolute minimum from 60° to 65° F., and the normal rainfall from 35 to over 150 in.

FLOWERING AND FRUITING. The small cream-coloured fragrant flowers, in grey-tomentose panicles, appear in January and February, and the fruit ripens in May and June. The light fruit (Fig. 14, *a*) has two straw-coloured wings less than 2 in. long, the nut being 0.25 in. long; it is thus capable of being blown to a considerable distance. As in other dipterocarps the seed germinates soon after reaching the ground, and quickly loses its germinative power. The tree seeds freely at frequent intervals.

GERMINATION (Fig. 14, *b-d*). Epigeous. The shell of the nut cracks and the radicle emerges from near its apex, curving downwards and rapidly forming a taproot. Meanwhile the elongation of the hypocotyl withdraws from the fruit the fleshy cotyledons, which expand and are carried above ground, the young shoot appearing from between them.

THE SEEDLING (Fig. 14).

Roots : primary root moderately long and thick, terete, tapering, woody : lateral roots moderate in number or numerous, short to long, fibrous, distributed down the main root. **Hypocotyl** distinct from the root, 0.8–1.5 in. long, terete, slightly fusiform, minutely tomentose. **Cotyledons :** petiole 0.15 in. long, thick, somewhat flattened, minutely pubescent : lamina divided nearly to the base into two thick fleshy angular lobes 0.25–0.4 in. long. **Stem** erect, terete, woody, young parts minutely tomentose. Internodes, first (between cotyledons and first foliage leaves) 1.5–2.5 in. long, subsequent internodes 0.1–1.3 in. long. **Leaves**, first pair opposite, subsequent leaves alternate. Stipules 0.05–0.1 in. long, narrow triangular acuminate, tomentose, caducous. Petiole 0.1–0.15 in. long, minutely tomentose. Lamina, first pair 1.2–1.9 in. by 0.35–0.6 in., subsequent leaves 0.7–2.7 by 0.25–0.9 in. long, ovate lanceolate, acute or acuminate, base rounded or acute, entire, glabrous, but midrib on under surface of young leaves minutely pubescent and margins sometimes with a fringe of minute hairs; lateral veins 6–12 pairs.

Seedlings ordinarily attain a height of 3–8 in., with 6–12 leaves, by the end of the first season. In Coorg young plants four years old attained an average and maximum height of 1 ft. 10 in. and 3 ft. 2 in.

SILVICULTURAL CHARACTERS. The main silvicultural characters are those of the hygrophilous type of dipterocarps (see p. 32). Foulkes says it has a long deep taproot with few lateral roots; this would enable it to grow on comparatively dry situations, as it appears to do at times, the root penetrating to moister strata below. He adds that it is a strong shade-bearer, but that light requires to be admitted in the case of saplings more than three years old. Bourdillon says that poles are not often seen in dense forest, as they cannot bear very heavy shade. The tree is more light-demanding than *Balanocarpus*, with which it is associated in Tinnevely.

NATURAL REPRODUCTION. The tree regenerates naturally with freedom in South Canara. Foulkes remarks that it does so better than any other species except *Xylia*. Bourdillon says that seedlings may be found under the parent



FIG. 14. *Hopea parviflora*. Seedling $\times \frac{1}{2}$.
 a, fruit ; b-d, germination stages (near large wing removed in b and c) ; e, seedling one month old ; f, seedling five months old.

trees in vast numbers, but that they cannot establish themselves under heavy shade ; he adds that young trees are often seen springing up on land that has been cleared by hillmen and abandoned, and also on abandoned coffee estates under the shade of bushes and small trees. The light winged seed is adapted for regeneration on open spaces of this kind. Cleanings have been found to be beneficial to the establishment of natural reproduction.

Experiments carried out by Mr. H. Tireman in Coorg in recent years indicate that the seedlings require protection from the sun only in the first year or two, after which the removal of the cover greatly stimulates growth and assists in the establishment of reproduction, which often appears in dense masses, particularly in small clearings.

Hopea parviflora sometimes regenerates freely in the more open teak plantations of Malabar, forming an underwood to the teak (see Fig. 15).

As regards the effect of cutting *Strobilanthes* on the natural reproduction of this tree, Forest Ranger C. P. Garudachellam¹ notes that in the South Canara district over an experimental area of 5 acres covered with *Hopea* seedlings *Strobilanthes* was cut during 1913-14, and that an inspection after the heavy monsoon rains showed that this greatly stimulated the development of the *Hopea* seedlings.

ARTIFICIAL REPRODUCTION. In South Canara crops have been raised successfully by broadcast sowings in moist situations or under moderate shade ; these sowings have proved cheaper and more successful than transplanting seedlings, an operation which requires a good deal of care. Overhead cover requires to be removed after two or three years. Bourdillon says that in Travancore artificial propagation has not been attended with success : seeds sown in nursery beds do not readily germinate, and the plants which are produced are sickly. He adds that plants collected from the forest and planted out fail in large numbers, probably owing to their long taproots having been broken in moving them.

SILVICULTURAL TREATMENT. Mr. P. M. Lushington, writing of the treatment of *Hopea* (white kongu) and *Balanocarpus* (black kongu) in Tinnevely, says : ' The difference in the leaf and the nature of the seed must entail considerable differences in the silviculture of the two species. The black kongu, with its large and heavier leaf, is more of a shade-lover than the white variety. The difference in the seed is evidently due to the same cause. The lightness of the white kongu seed, with its attached wings, causes it to spread over a much larger distance and to settle in places where there is plenty of light. The heavy seed of the black kongu falls directly to the ground, and under the shade of the parent tree hundreds of young seedlings readily spring up. A mixed forest of the two kinds of kongu would be similar to the mixture of oak and beech in Europe, and in order to favour white kongu there must be larger clearance overhead. There should be no difficulty, therefore, in raising pure forests of the two species, taking precautions that the white variety is not suppressed. As the white variety springs up more quickly when a clearance is made, it should get a start of the black which will be favourable to both species. As a result it appears that a treatment of regular high forest with thinnings should be particularly applicable, and the more the two trees can

¹ Ind. Forester, xlii (1916), p. 247.

be induced to grow in unison the better should be the results. This seems to be the ideal to be aimed at, but will take many years to carry out.'

He proposes to carry out this treatment by a gradual opening of the canopy by girdling inferior species in order to free existing advance growth and to induce further regeneration where kongu seed-bearers are present: this opening would be more drastic round white than round black kongu seed-bearers.

This treatment is somewhat similar to that advocated for *Dipterocarpus turbinatus* in Burma; as in the case of this species, so in the case of *Hopea* and *Balanocarpus*, the use of fire for preparing the ground will no doubt stimulate regeneration where it can be applied. This treatment is one which may be considered to be generally applicable to dipterocarps of the hygrophilous type.

RATE OF GROWTH. The rate of growth cannot be ascertained from ring-countings, as there are no annual rings in the wood. Bourdillon states that the best of a group of trees planted in Travancore measured 61 ft. in height and 7 in. in diameter at breast-height in ten years, and a tree fifteen years old was 9 in. in diameter, though it had been retarded in growth by the cutting of some of its roots. He also quotes the following measurements of a tree planted in the forest bungalow compound at Malayattur in Travancore in 1888:

Age. Years.	Height. ft.	Girth. in.
10	26	18
11	—	20 $\frac{1}{4}$
12	47	23 $\frac{1}{2}$
14	—	27 $\frac{1}{2}$

Taking the measurements at twelve years, a mean annual girth increment of about 2 in. and a mean annual height increment of about 4 ft. are obtained: this is rapid growth, though the conditions may have been exceptionally favourable. Bourdillon considers from personal observation that the tree grows slowly for the first six years of its existence, and after that more rapidly. Mr. Lushington considers that no tree should be felled until it is 8 ft. in girth. Very large trees are often unsound.

3. *Hopea Wightiana*, Wall. Vern. *Haiga*, *hiral bogi*, Kan.; *Kavsi*, Mar.; *Ila pongu*, Tam.

A large tree with a stout stem. Bark thin, smooth, exfoliating in large rectangular plates, white or yellowish inside. Wood hard and heavy, much used for building.

As this tree is sometimes associated with *H. parviflora*, Bourdillon's key to the two species may be quoted:

Leaves 3 $\frac{1}{2}$ in. by 1 $\frac{1}{2}$ in., petiole $\frac{1}{2}$ in., panicles grey-tomentose, flowers $\frac{1}{2}$ in. across, cream-coloured, wings of the fruit straw-coloured, under 2 in. long . . . *H. parviflora*.

Leaves 5-8 in. by 2-3 in., petiole $\frac{1}{2}$ in., panicles glabrous, flowers $\frac{1}{2}$ in. across (Talbot says 0.5 in.), yellow tinged with red, wings of the fruit red, 2-3 in. long . . . *H. Wightiana*.

Round echinate galls are often found in the axils of the leaves.

DISTRIBUTION AND HABITAT. Evergreen forests of the Western Peninsula



FIG. 15. Teak plantation with natural underwood of *Hopea parviflora*, South Malabar.



FIG. 16. *Pentacme suavis* in semi-indaing forest of good quality, Mōngmit State, Upper Burma.

from the Konkan southwards to Tinnevely: often gregarious along river-banks and in the low coast country. Bourdillon says that in Travancore it is much less common than *H. parviflora*, and as far as he has observed, is confined to the lower elevations: in former times, when evergreen forests spread all over the low country, it was doubtless common enough, but at present only a few trees are met with in groves or on the sides of rivers. In its natural habitat the absolute maximum shade temperature varies from 95° to 100° F., and the absolute minimum from 60° to 65° F., the normal rainfall varying from 35 to over 150 in.

FLOWERING AND FRUITING. The flowers, which are yellow or white tinged with red, appear in March and April, and the fruits ripen in May and June; the wings are 2-3 in. long by $\frac{1}{2}$ in. wide, bright crimson, and the trees are very handsome when covered with the crimson fruits towards the end of the hot season. As in other dipterocarps, the seed germinates soon after reaching the ground.

SILVICULTURAL CHARACTERS AND TREATMENT. The main silvicultural characters are those of the hygrophilous type of dipterocarps (see p. 32). Beddome says that *H. Wightiana* var. *glabra* (*H. glabra*, W. and A.) coppices well. As far as is known the silvicultural treatment proposed for *H. parviflora* would be equally applicable to this species.

3. PENTACME, A. DC.

Pentacme suavis, A. DC. Syn. *P. siamensis*, Kurz; *Shorea siamensis*, Miq. Vern. *Ingyin*, Burm.

A large deciduous, usually gregarious tree, reaching a height of 80 ft. or more and a girth of 10 ft. or over; Mr. A. Rodger records one of 16 ft. in the Ruby Mines district. Bark thick, rough with deep vertical fissures and with transverse cracks, dark grey, reddish brown inside. Wood very hard and durable, much in demand for building purposes. Lac is sometimes produced on this tree.

DISTRIBUTION AND HABITAT. Throughout Burma, in *indaing* and in dry deciduous forest. It extends to a good many localities where *Dipterocarpus tuberculatus* is absent or comparatively rare, as in parts of the dry zone of Upper Burma and on many dry ridges throughout the country. In Tenasserim it is less common than in other parts of the province.

Indaing forest, so typical of laterite formations, has already been described under *Dipterocarpus tuberculatus*, the *in* tree, which forms the principal constituent of the normal form of *indaing*: *Pentacme suavis* (*ingyin*) and *Shorea obtusa* (*thitya*) together are the two most important companions of the *in*, all three species occurring gregariously together. The relative proportion of *in* on the one hand, and *ingyin* and *thitya* on the other, varies considerably; the two latter usually occur together, though there are exceptions to this, while the *in* is occasionally found without the other two. *Ingyin* and *thitya*, on the other hand, are often found without *in*, particularly on ridges and other dry localities, for they appear to be able to survive in less favourable situations than the latter species. Apart from laterite, they are most commonly found on dry sandstone formations and sometimes on red clay. They may be

said to occur in varying types of forest from *indaing* of the normal type through various forms of semi-*indaing* to dry deciduous mixed forest with varying associates, and may be found even in fairly moist types of forest. Fig. 16 shows a good quality of *indaing* forest in which *Pentacme suavis* is the most plentiful species.

Some examples of the occurrence of this tree may be quoted. On some of the dry ridges of the Chindwin drainage *ingyin* and *thitya* occur on sandy, often shallow soil, associated with oaks (*Quercus spicata* and *Q. Brandisiana*), *Buchanania latifolia*, *Strychnos Nux-blanda*, *Garuga pinnata*, *Gardenia erythroclada*, and *Cycas siamensis*. In parts of the dry zone of Upper Burma they occur on sandstone formations, in which silicified wood (Burmese *ingyin-kyark*) is sometimes found, the soil often being poor and shallow. Here *ingyin* and *thitya* of rather small dimensions are found associated with other trees of stunted growth, of which the chief are *Terminalia tomentosa*, *Diospyros burmanica*, *Phyllanthus Emblica*, *Acacia leucophloea*, *A. Catechu*, *Buchanania latifolia*, *Tectona Hamiltoniana*, *Xylia dolabriformis*, *Odina Wodier*, *Schleichera trijuga*, *Dalbergia paniculata*, and *Cassia renigera*. In the driest places *ingyin* and *thitya* give place to *Tectona Hamiltoniana*, *Terminalia Oliveri*, *Acacia leucophloea*, *A. Catechu*, and other species typical of the dry zone.

In the Pegu Yoma, where the formation is sandstone and shale, *ingyin* and *thitya* become more plentiful towards the north of the range, where the climate and the type of forest are drier than in the south. Thus in the Sinthè reserve of the Pyinmana division, which borders on the dry zone, the rainfall being about 40 in., *ingyin* and *thitya* are the commonest species, forming 13.2 per cent. of the total growing stock as against 7.6 per cent. for teak and 1.2 per cent. for *in*. In the Pozaungdaung reserve of the same division they form 10.4 per cent. of the growing stock as against 7.1 per cent. for sound teak, while in the East Yoma, Satsuwa, and Tindaw reserves of the Thayetmyo divisions they form 7 per cent. of the stock as against 15 per cent. for teak. The reserves in question are primarily teak reserves, the *thitya* and *ingyin* occupying mainly the drier sandstone ridges, and these figures therefore indicate that a very considerable quantity of *ingyin* and *thitya* occurs along these ridges in the drier types of mixed deciduous forest in the Pegu Yoma. Associated with them in such localities are *Pterocarpus macrocarpus*, *Terminalia tomentosa*, *Odina Wodier*, with rather stunted teak and *Xylia dolabriformis*, and often *Dipterocarpus tuberculatus*. Where bamboos are present the commonest species are *Dendrocalamus strictus* in the driest situations, and *Oxytenanthera albociliata*, *Cephalostachyum pergracile*, and *Bambusa polymorpha* elsewhere.

Ingyin and *thitya* are not necessarily confined to poor dry localities. They sometimes occur in fairly moist fertile tracts, even associated at times with *kanyin* (*Dipterocarpus turbinatus* and *alatus*), and here the trees attain very large dimensions. There is often a comparatively heavy undergrowth in such localities. In the better types of *indaing* forest, also, where *ingyin* and *thitya* are mixed with *in*, they often attain large size, trees 10 or 12 ft. in girth being not uncommon.

As regards climatic conditions, *ingyin* and *thitya* in their natural habitat occupy regions where the absolute maximum shade temperature varies from 100° to 110° F., the absolute minimum from 35° to 50° F., and the normal

rainfall from 30 to 100 in. or more. Where the rainfall is below 40 in. the trees are somewhat stunted.

LEAF-SHEDDING, FLOWERING, AND FRUITING. *Pentacme suavis* is the most deciduous of all the dipterocarps. In fertile localities it is leafless for a comparatively short time or may be scarcely quite leafless, but in dry situations it may drop its leaves towards the end of January or early in February and remain leafless till April. The large inflorescences of showy yellow fragrant flowers appear in March, when the tree is leafless or nearly so, and the fruits ripen in May and June. The fruit is five-winged, three of the wings being larger than the other two; the larger wings are about 3-3½ in. long. Like that of other dipterocarps, the seed germinates soon after falling, and will not keep any time; it is also subject to the attacks of insects.

SILVICULTURAL CHARACTERS. *Pentacme suavis* belongs to the xerophilous type of dipterocarps (see p. 32), and, with *Shorea obtusa*, represents the limit of that type in the Indo-Burman region, extending into drier situations, and occurring on poorer soil and more rocky ground than any of the other dipterocarps. Its adaptations for persisting in such localities are seen in its comparatively thick rough bark, its long taproot, its deciduous character, and the red colour not only of the young leaves, but also of the older ones. Further, Ryan and Kerr¹ note the occurrence of two well-marked varieties, one in which the young shoots and stipules are glabrous and the other in which they are tomentose, the latter being characteristic of dry situations and the former of more fertile localities. The period of growth is short, commencing at the end of March and usually continuing for a month to six weeks, after which it ceases. The tree coppices well up to a moderate size, and Ryan and Kerr note that they have found it producing root-suckers very occasionally; this would indicate a further special adaptation, not possessed by dipterocarps in general, for surviving in dry localities.

NATURAL REPRODUCTION. As a rule the tree regenerates freely, but in years of deficient rainfall the seedlings are known to die from drought in the monsoon months in dry situations. It has not yet been determined if dying back for some years, with subsequent establishment of the seedling, takes place with this species. As in the case of the sal, successful germination depends on the timely commencement of the rains when the fruits fall, since the seed loses its vitality quickly and fails to germinate if it lies any time on dry ground, particularly if exposed to the sun.

4. SHOREA, Roxb.

Seven species in the Indo-Burman region. Fruit with three long wings.

Species 1. *S. robusta*, Gaertn. f.; 2. *S. Tumbuggaia*, Roxb.; 3. *S. obtusa*, Wall.; 4. *S. Talura*, Roxb.; 5. *S. assamica*, Dyer.

1. *Shorea robusta*, Gaertn. f. Sal. Vern. *Sál*, *sála*, *sálwa*, *sákh*, Hind.; *Sakwa*, Nep.; *Shál*, Beng.; *Sálwa*, *soringhi*, Uriya.; *Sarai*, *rinjal*, C.P.; *Gúgal*, Tel.

A large gregarious tree, seldom quite leafless, with shining foliage, the mature leaves somewhat coriaceous, ovate-oblong, usually about 4-8 in. long.

¹ Journ. Siam Soc., viii (1).

Crown conical or elongated in youth, afterwards rounded with a strong branch-system. Bole clean and straight in forest-grown trees. Bark of saplings greyish brown, smooth, with a few deep longitudinal cracks; that of older trees dark brown, 1-2 in. thick, rough, with deep longitudinal furrows. Sapwood small, pale coloured, heartwood brown, hard, cross-grained, very strong and durable, seasoning slowly. This is one of the most important timber trees of India; the wood is extensively used for building construction of all kinds, railway sleepers, wagons, and a large number of other purposes. The tree when tapped yields a whitish resin which is burnt as incense and used for caulking boats. Apart from the technical properties of its timber, the gregariousness of the sal renders it specially important in that the timber is obtainable in abundance within the tracts occupied by it.

In favourable localities the sal reaches a height of 120 ft. and a girth of 12 ft. or more. According to Brandis, in the gorges at the foot of the hills in Nepal it may attain a height of 150 ft. with a clear stem of 60-80 ft. and a girth of 20-25 ft. A tree 25 ft. 8 in. in girth was measured in 1910 in the Chilkia range of the Ramnagar forest division, United Provinces. Gamble mentions a tree in the valley of the Great Rangit, in the Darjeeling hills, which was 161 ft. high, 86 ft. to the first branch, and 10 ft. 8 in. in girth at 4 ft. from the ground. Such dimensions, however, are quite exceptional; under average conditions the tree ordinarily attains a height of 60-100 ft. with a girth of 5-7 ft., while under less favourable conditions it becomes stunted, reaching a maximum height of only about 30-40 ft.

GENERAL DISTRIBUTION. The sal occupies two main regions separated by the Gangetic plain, namely, the northern and the central Indian regions. In the former the extreme north-western limit is in the Kangra district of the Punjab, where there is an outlying area in which the growth of the trees is stunted. The main and almost continuous stretch of sal forest in the northern region commences with the Kalesar forest in the Ambala district, on the right bank of the Jumna, and stretches along the sub-Himalayan tract as far east as the Darrang district of Assam. In places the sal extends some distance out into the plains; it also runs into the outer Himalayan valleys, and ascends the outer hills to 4,000 ft. and occasionally to 5,000 ft. South of the Brahmaputra river in Assam it is found in the Garo hills, Nowgong, Kamrup, and the Khasi and Jaintia hills: there is still a considerable area of sal in the Jirang state and a smaller area in the Nongkhlaw state, but the sal tracts are scattered and much cut up by shifting cultivation.

In the central Indian region the sal commences near the Ganges in the Santal Parganas and extends southwards through Chota Nagpur and the Orissa Feudatory States to the Madras Presidency, where it occurs chiefly in the Ganjam district and to a small extent in Jeypore and in the Palkonda range of Vizagapatam. To the west there are considerable areas of sal forest in the Central Provinces, chiefly in the Bilaspur, Mandla, Balaghat, Jubbulpur, and Raipur districts.

Although the general distribution of the sal is governed mainly by climate, its local distribution is governed largely by conditions of geology and soil.

CLIMATE. The regions in which the sal is found vary widely as regards both temperature and rainfall. In the western Himalaya it ascends in places

to regions where it encounters occasional snowfall, and where the maximum shade temperature is not much above 90° F. In the valleys of the western sub-Himalayan tract, as well as in parts of the central Indian region, it is exposed to severe frost, and suffers considerably from its effects. In parts of Chota Nagpur and the Central Provinces it grows in localities where the temperature may rise to 115° F. or more, and where frost is unknown. In the eastern part of its northern region it thrives in a moist but equable climate, where the normal rainfall may be as much as 180 in. and the maximum temperature is not much above 100° F. Nowhere does it enter regions where the climate approaches aridity. Taking its habitat as a whole, the absolute maximum shade temperature varies from about 93° F. at high elevations to about 117° F. in the hottest part of Chota Nagpur, and the absolute minimum varies from under 30° F. to about 45° F., while the normal rainfall varies from 40 to 180 in.

In its northern region its range on the west is limited by the fact that it begins to enter localities which are too dry and in which the extremes of temperature are too great: in the Kangra valley the rainfall varies from 50 to 100 in., which is considerably higher than in the submontane tracts outside, and this probably accounts for the existence of a small area of sal as an outlier in that locality. On the east, in Assam, the range of the sal is limited mainly by the humidity of the climate, which induces a luxuriant growth of evergreen species and a dense undergrowth, resulting in soil conditions unfavourable to the establishment of seedlings, and producing a struggle for existence against shade-bearing competitors which the sal is unable to survive. Similar unfavourable conditions have been produced artificially farther west in the Duars by prolonged fire-protection, as will be explained later.

In the central Indian region the limits of the sal are defined partly by climatic conditions, in that it does not extend into the driest tracts, and partly by the local geological formation.

TOPOGRAPHY, GEOLOGY, AND SOIL. Sal forests occur both in hilly country and on flat ground. In the former the sal is found, as a rule, in stunted form on the ridges; in dry hot localities it avoids the ridges altogether, seeking the moister and cooler aspects and depressions. It grows best on the lower slopes and in the valleys where the soil is deep, moist, and fertile. Some details of its occurrence in different situations are given below.

As regards geology and soil, the sal is found on a variety of geological formations, and is capable of growing on various types of soil provided the soil water-content is neither too low nor too high to enable it to establish itself. Within its habitat it avoids soils which, although otherwise thoroughly suitable for its growth, become too dry for its survival in the season of scanty rainfall. Mr. Hole¹ has shown that sal seed germinates very successfully even in pure sand provided it is sufficiently moist, but that the seedlings die of drought if the soil water-content falls to 3 per cent. in sand or sandy loam and to 10 per cent. in loam. This accounts for the well-known fact that sal is never found in the sandy and shingly river-beds which are so common in the sub-Himalayan region. Here, although the seed may germinate in the rains, the seedling cannot survive the dry season: these river-beds are occupied

¹ Ind. For. Records, vol. v, pt. iv, p. 17.

by forests of *Acacia Catechu* and *Dalbergia Sissoo*, or at a later stage by dry miscellaneous forest. Swampy tracts in the neighbourhood of the sal forests are also avoided by the sal, which cannot survive the permanent excess of soil moisture; such ground is occupied by typical swamp trees, such as *Eugenia Jambolana*, *Trewia nudiflora*, *Diospyros Embryopteris*, *Bischoffia javanica*, and others. It is not the water as such that the sal avoids, but the bad drainage causing a want of sufficient aeration in the soil: actually the tree will grow with its roots in running water.

The most favourable soil for the growth of the sal is a well-drained moist deep sandy loam with good subsoil drainage, and hence the tree thrives well on deep boulder deposits overlain by a sufficient depth of fertile porous loam. On some of the deep boulder deposits and elevated river terraces flanking the outer Himalaya the sal thrives extremely well and reaches large dimensions. An excess of clay in the subsoil, on the other hand, produces stunted and unhealthy growth, as will be seen in the description of forest types given below. In the alluvial tracts of the plains the sal is usually of better quality on the high ground which frequently skirts the banks of streams, and may extend for a distance of some hundreds of yards from them, than on the lower ground farther from the streams. The explanation is probably to be found in the greater porosity of the soil and the better drainage in the case of the high ground near streams than on the lower ground where water collects annually in the rains, bringing with it fine clayey particles which settle year after year in the soil and render it impervious to air and water.

The distribution and character of the sal forests of the sub-Himalayan tract, as will be seen presently, are influenced in no small degree by the *bhabar* and *tarai* formations. The former is a stretch of deep dry boulder deposit skirting the base of the outer hills. It commences some distance to the east of the Ganges and stretches eastward to Assam, with occasional breaks. In the United Provinces its maximum width is about 13 miles, and it slopes down from about 1,200 ft. at the base of the hills to about 800 ft. at its outer limit. This *bhabar* deposit is extremely porous, and all but the larger rivers and streams sink into the ground on issuing from the hills, their beds remaining dry except in the flood season. The surface of the *bhabar* tract is waterless, though cultivation is carried on by irrigation with the aid of masonry canals and channels. The natural water flows at a great depth below the surface until it reaches the outer limit of the *bhabar* tract. Here it is brought to the surface by underlying clay deposits, and a series of springs marks the commencement of the *tarai*, a tract of swamps, quicksands, and streams full of water, sometimes of considerable depth. In the United Provinces the maximum breadth of the *tarai* is about 8 miles, and it slopes gently down from about 800 ft. to 650 ft. at its outer limit, where the land of swamps is left behind and the plains of northern India commence. The types of sal forest on the *bhabar*, *tarai*, and plains will be considered in the next section.

As regards underlying rock, in the sub-Himalayan tract the sal occurs on the older Himalayan rocks of the outer ranges, consisting chiefly of shale or mica schist with occasional limestone; on the tertiary sandstones, shales, and conglomerates of the Siwalik range flanking the Himalaya proper; and on the deep boulder deposits skirting the base of the hills and lining the outer

valleys in many places. Where pure limestone appears within its region, the sal seems to avoid this rock ; it thrives well, however, where the soil consists partly of limestone debris, and it may be concluded that the objection is not to the lime itself but to the physical properties of the limestone rock, which is too dry for the sal. In the Dun sal avoids the dry shallow soil overlying calcareous tufa, which forms a hard pan. In the sub-Himalayan tract of Assam the sal occurs on the schists of the outer Himalaya and on granitic rock, as on Singri hill in Darrang, as well as on the sandstones and conglomerates of the lower hills and the deep boulder beds flanking the outer ranges. In the Guma reserve of Goalpara it occurs on a red lateritic formation overlying boulder beds.

In its central Indian or peninsular region the sal occurs on a variety of geological formations, of which the chief are gneiss, mica schist, quartzite, shale, sandstone, and laterite ; it is found occasionally on limestone, and also occurs on alluvial ground overlying older rocks. The sal does not necessarily occur on all these rocks in different localities. In the drier regions it may be absent from a geological formation which it frequents in a moister climate, while the local form of a particular rock may effect the occurrence of sal on it. The central Indian region comprises for the most part forests of a somewhat dry type, and hence the occurrence of sal is determined largely by the hygroscopicity of the rock and soil. A noteworthy instance of this is its almost complete absence on the Deccan trap, where its place is taken by the teak. In the few cases in which sal enters the trap region it occurs, as a rule, sparsely and in stunted form, but there are exceptional cases in which sal forest of very fair quality occurs on trap. This avoidance of trap is evidently due to the fact that this rock and the soil produced by it are not sufficiently retentive of moisture, since on the edge of the trap a comparatively small admixture of decomposing laterite may produce a soil on which sal can thrive. Where sal does grow on trap this is no doubt due to the fact that the subsoil water-content is higher than is usually the case on this geological formation. Sal thrives well on laterite provided it is in a sufficiently decomposing state to produce some depth of soil : on hard laterite with a shallow soil it is stunted or may be entirely absent. The tree is not averse to highly ferruginous soils. Sal forest of very fair quality occurs in Singhbhum on hills consisting of haematite which is in process of being mined ; the sal roots penetrate through even the most highly ferruginous portions of the ore.

Among other examples of the effect of geological formation on the distribution of the sal, it may be mentioned that in the Bilaspur district of the Central Provinces sal occurs mainly on gneiss and clay schist, stopping short on the appearance of sandstone, which is here almost in the form of quartzite, and avoiding limestone ; the two latter formations appear to be too dry for the establishment of the sal. In the Jubbulpur district various geological formations meet ; sal is, practically speaking, confined to the Upper Gondwana formation, consisting of earthy sandstones and clays, while teak adheres to the trap and Vindhyan areas, the latter comprising more porous sandstones with shale and limestone.

TYPES OF FOREST AND LOCAL OCCURRENCE. The sal is one of the most gregarious of Indian trees ; it tends to regenerate in masses where conditions

are favourable, and to grow up in more or less even-aged crops of varying extent in which it is pure or forms the bulk of the stock in mixture with other species. Even-aged more or less pure crops of appreciable extent are particularly characteristic of flat or gently sloping ground which was formerly devoid of tree growth, for example, grassy savannahs or abandoned cultivation ; here, if conditions are favourable, the sal springs up in gregarious masses, often forming crops of great density (see Fig. 17). Where grassy blanks occur within the sal forests the sal tends to spread gradually into them and to re-stock them. Fig. 18 shows sal pole forest bordering a grassy blank, and gives an idea of the gregarious character of the tree. On grassy savannahs the sal also tends to spread outwards from isolated seed-bearers or groups of seed-bearers ; small pure even-aged groves of sal are thus formed (Fig. 19). These in course of time spread outwards by degrees, sometimes forming a series of even-aged crops in different stages of development.

Although the natural tendency of the sal is to spring up gregariously and to form even-aged crops, it also occurs frequently in uneven-aged crops, and may also be found more or less scattered by single trees or in small patches among various other species. This is frequently seen in hilly or broken country, where conditions for reproduction and growth constantly vary from place to place within narrow limits of area. It is also seen in cases where sal is gradually encroaching into miscellaneous forest, or where it is being gradually ousted by other species. Cases of the former are frequent in the *bhabar* tract of the United Provinces, while cases of the latter may be noticed in the moist forests of the Bengal Duars, where the sal is being ousted by evergreen species.

The sal is associated with various other species, some of which are characteristic of distinct types of sal forest. As these companion species differ to some extent in different localities they will be considered in dealing with local types. In some localities sal in mixture with bamboos (*Dendrocalamus strictus*) is not uncommon, particularly on hilly or undulating ground.

Sal forests in general can be separated into two extreme types, the dry and the moist types ; between the two various gradations occur. The dry type is characteristic of dry and often hilly country, denuded or hard ground, and shallow soil ; in this type the commonest companion of the sal is *Buchanania latifolia*, and in some localities *Diospyros tomentosa* or *D. Melanoxydon*. Dry types are well represented in the central Indian region and in the western part of the northern region. The extreme of the moist type is seen in the moist sal forests of Bengal and Assam, where the sal is associated with various evergreen species. Intermediate types, tending towards the moist rather than the dry type, may be found in many parts of the United Provinces and in the fertile valleys of Chota Nagpur.

Sal forests are inseparably connected with grass-lands, which may consist of small grass-covered blanks within the forests or of extensive savannah tracts within or adjacent to them, and into which the sal tends to spread where conditions are favourable. The savannah grasses are excellent indicators of the suitability or otherwise of a given locality for the growth of sal. An account of the more important grasses of the Dehra Dun neighbourhood has



FIG. 17. *Shorea robusta*, dense even-aged pole crop, Dehra Dun, United Provinces.



a. 18. *Shorea robusta* pole forest along edge of grassy blank, in which natural reproduction is gradually appearing, Dehra Dun.



FIG. 19. *Shorea robusta*, dense pole crop sprung from isolated seed-bearers on a grassy plain, Patli Dun, United Provinces.

been written by Mr. Hole.¹ The most characteristic savannah grass of the sal tracts is *Saccharum Narenga*, Wall., the *kanual* of northern India or *bata* of Assam, a tall grass, the culms of which attain 16 ft. in height. Its presence denotes soil conditions eminently suitable for sal, and it is the dominant grass of the sal tracts, not only in open savannahs, but also beneath the partial shade of the forest where the canopy is sufficiently open. Frequently associated with it, and also denoting soil conditions suitable for sal, is *Anthistiria gigantea*, Cav., the giant spear-grass, a variety of which, however, occurs in low-lying ground unsuitable for sal. *Saccharum spontaneum*, Linn., the *kans* grass, sometimes occurs with *S. Narenga* in localities suitable for sal, but it is also frequent on low-lying moist ground where sal will not grow, while a variety of the same grass is found on sandy soil in dry river-beds incapable of supporting sal.

Saccharum Munja, Roxb., the *munj*, is the dominant grass on the sand and shingle of dry river-beds in the neighbourhood of sal forests; it is associated with *Acacia Catechu* and *Dalbergia Sissoo*, but denotes soil conditions too dry for sal to thrive. With it, and denoting similar or even less favourable conditions, are *Andropogon monticola*, Schult., *Aristida cyanantha*, Steud., and *Triraphis madagascariensis*, Stapf. The last named, however, sometimes occurs in very dry types of sal forest, as in Goalpara. *Erianthus Ravennae*, Beauv., is a tall grass not unlike *Saccharum Munja* in general appearance, with culms reaching 20 ft. in height. Although sometimes associated with *S. Narenga* in sal tracts, it denotes a higher degree of soil moisture than the latter grass, and is more typical of the moist mixed forests.

Imperata arundinacea, Cyrill., the *siru*, well known in Burma as *thekkè*, occurs in sal tracts, and denotes widely varying soil conditions. It occurs with *Saccharum Narenga* in localities suitable for sal: here it often becomes dominant as a result of the weakening of *S. Narenga* by constant cutting or grazing, which prevents the latter forming seed, whereas *Imperata* seeds freely under such conditions, while its creeping stolons make it more resistant to fire and other injuries and more difficult to eradicate by cultivation. Thus *S. imperata* often becomes dominant on fire-lines or roads running through tracts of *S. Narenga*. *S. imperata* very commonly indicates stiff clayey water-logged ground unsuitable for sal. It is, however, also found on dry sandy soils in dry sal or mixed forest, as on the southern slopes of the Siwaliks, or on poor denuded ground in dry open sal forest, as in the Jaspur forest near Ramnagar.

The more characteristic tall grasses of the low-lying wet and swampy tracts which are too moist for the growth of sal are *Phragmites Karka*, Trin., the *nal* or *narkal*; *Arundo Donax*, Linn., the giant reed; *Saccharum fuscum*, Roxb., the *retwa*; and *Saccharum procerum*, Roxb., the *ekra* of the low-lying savannahs of Bengal and Assam.

The local occurrence of the sal in the principal sal-bearing tracts may now be considered.

Punjab. In the small outlying sal areas of the Kangra district and the Siwalik hills of the Hoshiapur district the sal is at its northern limit, and occurs in stunted form. Its extreme limit in the Kangra district is on the

¹ R. S. Hole: On some Indian Forest Grasses and their Oecology. Ind. For. Mem., vol 1, Bot. Ser. I, 1911.

west bank of the Beas on an isolated hill, where with *Quercus incana* it forms an underwood to *Pinus longifolia*. Farther east in the Siwaliks it occasionally forms pure patches on flat-topped hills, but as a rule occurs as an underwood to *Pinus longifolia*. The rainfall is about 50–60 in. The only other sal tract in the Punjab is the Kalesar forest in the Ambala district on the west bank of the Jumna river. As it is near its northern limit, and suffers from frost the sal does not attain large dimensions. This forest marks the western limit of the great sub-Himalayan sal tract which stretches eastward to Assam.

United Provinces. Sal forests occur in a more or less continuous belt along the sub-Himalayan tract and outer hills from the Jumna to the Gandak river, and extend some distance into Nepal. The chief companions of the sal are *Terminalia tomentosa* (often on clay), *T. belerica*, *T. Chebula* (local), *Lagerstroemia parviflora*, *Eugenia Jambolana* (in moist types), *E. operculata* (especially in grassy tracts), *Adina cordifolia*, *Stephegyne parvifolia*, *Stereospermum suaveolens*, *Ougeinia dalbergioides*, *Miliusa velutina*, *Saccopetalum tomentosum* (Oudh), *Holarrhena antidysenterica*, *Wrightia tomentosa*, *Mallotus philippinensis*, *Garuga pinnata*, *Kydia calycina*, *Buchanania latifolia* (common in the drier and hill types), *Schleichera trijuga*, *Odina Wodier*, *Cassia Fistula*, *Anogeissus latifolia*, *Butea frondosa*, *Bauhinia malabarica*, *Casearia glomerata*, *C. tomentosa*, *Bridelia retusa*, *Dillenia pentagyna* and *D. aurea* (plains forests of Oudh), *Careya arborea*, *Phyllanthus Emblica*, *Diospyros tomentosa* (in dry types), *Semecarpus Anacardium*, *Randia dumetorum*, *Gardenia turgida* (on grass-lands), *Croton oblongifolius* (Oudh), *Cordia Myxa*, *Ehretia laevis*, *Grewia* spp. and species of *Ficus*, of which the commonest is *F. bengalensis*.

The most important climbers in the sal forests are *Bauhinia VahlII*, *Spatholobus Roxburghii*, and *Millettia auriculata*.

The sal forests of the United Provinces may be classified broadly, according to topography, into (1) forests of the hills and narrow valleys, (2) forests of the river terraces, (3) forests of the *duns*, (4) forests of the submontane and *bhabar* tracts, (5) forests of the *tarai* and plains. This classification is a somewhat arbitrary one, and it is not always easy to draw a sharp line between the broad classes; a classification of this kind, however, is convenient for descriptive purposes.

1. The hill forests vary greatly in type and quality. In the outer Himalaya the sal ascends to 4,000 ft., and exceptionally to 5,000 ft. Towards its upper limit it is associated, in somewhat stunted form, with *Pinus longifolia*. In a few places the pine descends into the valleys, where it may be found mixed with the sal: here the latter suffers from frost, and in fire-protected areas the pine is tending to spread and supplant it. On the upper and drier hill-slopes the sal occurs mainly in patches in moist depressions and on cool aspects, the hotter and more exposed slopes being clothed, as a rule, with dry mixed forest. On the upper slopes the sal is usually stunted; its commonest companion here is *Buchanania latifolia*. East of the Ganges the sal is often associated with bamboos (*Dendrocalamus strictus*). On the lower slopes and in the ravines, where the soil is moist and fertile, it often reaches very large dimensions, and produces a tall straight bole; its chief companions here are *Terminalia tomentosa*, *Adina cordifolia* of large size, and moisture-loving species such as *Eugenia Jambolana*, *Bischoffia javanica*, *Cedrela Toona*, and others. In some types of



FIG. 20. *Shorea robusta* forest of poor quality on stiff clay, Gorakhpur, United Provinces



FIG. 21. *Shorea robusta*, fire-protected *chandar* (on right of road) in April with thick growth of *ulla* grass (*Anthistiria gigantea*). Pilibhit, United Provinces.

outer hill forest the sal tends to grow less pure than in the plains, even where the locality suits it well. Many exceptions occur however, one of the most marked being seen in the case of gentle slopes on boulder formation, where dense nearly pure even-aged crops occur, sometimes of good quality, sometimes rather stunted. These crops appear to have arisen on former open blanks which were probably cultivated at one time. Areas formerly under cultivation in the outer hills are sometimes marked by the presence of sal pole crops with a plentiful admixture of *Ougeinia dalbergioides*. The latter is one of the first species to make its appearance on abandoned cultivation in these tracts, and the sal comes in when a favourable year for reproduction takes place, and makes its way through the *Ougeinia*.

Sal of small size is found throughout the dry Siwalik hills of the Saharanpur district, on tertiary sandstone, shale, and conglomerate. Here its chief associates are *Buchanania latifolia*, *Anogeissus latifolia*, *Stereospermum suaveolens*, *Ougeinia dalbergioides*, and in dry places *Cochlospermum Gossypium*; the palm *Phoenix humilis* frequently accompanies it, and on the higher ridges it is mixed with *Pinus longifolia*. It is seen at its best in sheltered ravines, where it forms gregarious patches of well-shaped poles which, however, do not reach a large size; in such places its chief companion is *Buchanania latifolia*.

2. Sal forests of the river terraces. These forests are situated at the base of the outer hills and along the chief river valleys on elevated flat or slightly sloping boulder terraces. The soil is deep, porous, and well drained, and the water-level is usually at a considerable depth, the terraces often being at a height of 150 to 200 ft. or more above the level of the stream. On these terraces sal occurs in well-stocked, even-aged, and remarkably pure crops. These terraces contain some of the best sal forest in the province, the growth and quality being as a rule excellent, and the trees reaching a great height in favourable localities.

3. Forests of the *duns*. The *duns* are broad valleys within the outer ranges of hills. The two best known are the Dehra Dun, lying between the Siwalik hills and the Himalaya proper, and stretching from the Jumna to the Ganges, and the Patli Dun, drained by the Ramganga river: there are also smaller and less well-known *duns*. These *duns* contain different well-marked types of forest, namely (a) riverain forests on recent alluvial beds of sand and gravel, the predominating species being *Dalbergia Sissoo* and *Acacia Catechu*; (b) dry mixed forests, containing *Acacia Catechu*, *Garuga pinnata*, *Bombax malabaricum*, *Odina Wodier*, *Holarrhena antidysenterica*, and other species; the dominant grass is *Saccharum Munja*, while on dry shingle-beds and other dry places occur also *Aristida cyanantha*, *Triraphis madagascariensis*, *Andropogon monticola*, and the dry form of *Saccharum spontaneum*; (c) moist mixed forest, with swamp forest as an extreme form; the dominant grass is *Erianthus Ravennae*, while the tree species vary with the degree of moisture, and include *Dalbergia Sissoo*, *Eugenia Jambolana*, *Bombax malabaricum*, *Garuga pinnata*, *Holarrhena antidysenterica*, and many others, and in the moistest parts *Cedrela Toona*, *Trewia nudiflora*, *Diospyros Embryopteris*, *Pterospermum acerifolium*, *Ficus glomerata*, *Bischofia javanica*, *Albizia procera*, and other swamp species; (d) sal forests, occupying the elevated ground well above the level of the rivers. The origin of the sal forests is to some extent

a matter for speculation, but in some cases there is undoubted evidence that they represent a stage in progressive succession subsequent to the dry mixed forest stage, the sal having gradually established itself in these forests as the soil became moister and more fertile with successive stages of tree-growth. The sal forests of the *duns* are characterized by the presence of grass-lands in which the dominating grass is usually *Saccharum Narenga*: many of these appear to be of artificial origin, and were probably at one time cultivated. These valleys are subject to severe frost, particularly in the low-lying parts, and reproduction is killed back, while severe damage is often done to saplings and poles. As the hills surrounding the valleys are ascended, the risk of frost damage becomes less. In spite of the frost the sal tends to spread into the grass-lands where soil conditions are favourable. Fig. 18 shows the edge of a sal forest in the Dehra Dun valley, with sal reproduction gradually establishing itself in an adjacent grassy blank subject to severe frost. The sal forests of the Dehra Dun valley are situated on deep boulder deposits with water at a great depth; where these deposits are overlain by fertile loam the sal reaches fair dimensions considering that the locality is near the northern limit of the species.

4. Forests of the submontane and *bhabar* tracts. The sal forests of the submontane tracts occupy broken ground or boulder deposits along the base of the outer hills; they vary much in type and quality. On deep boulder deposits and old terraces they resemble the forests of the river terraces, the crops being often even-aged and remarkably pure. On fertile ground, crops of excellent quality are produced along the base of the hills, for example in the Lakmanmandi and Sunmanthapla blocks to the east of Haldwani and in the Lachampur block to the east of Ramnagar. In the drier submontane tracts the forest is of a poorer type, and in places is mixed largely with *Buchanania latifolia*: this type of forest is exemplified on the gently sloping ground on the south of the Saharanpur Siwaliks. In some portions of the sub-Himalayan tract, for example outside the foot-hills in the Gonda district, the sal occurs on broken ground intersected by ravines; this ground is occupied in places by poor dry mixed forest, the sal occurring in pockets in the moister depressions. On the outskirts of this broken country, where the ground dips down to more level country and becomes moister, sal forest of excellent quality is found in a somewhat narrow strip, for example at Chandanpur. The *bhabar*, as explained above, is the deep waterless boulder tract which stretches in places along the base of the hills. The typical forests of the *bhabar* are not sal forests but dry mixed deciduous forests of a rather open character, in which the commoner trees are *Holoptelea integrifolia*, *Hymenodictyon excelsum*, *Bombax malabaricum*, *Odina Wodier*, *Garuga pinnata*, *Lagerstroemia parviflora*, and *Acacia Catechu*, while *Pterocarpus Marsupium* is common in the eastern Kumaun *bhabar*. In the river-beds occur forests of *Dalbergia Sissoo* and *Acacia Catechu*, while in moist situations *Trewia nudiflora*, *Eugenia Jambolana*, and other moisture-loving species are found. In the *bhabar* tract the sal forests occur in situations where the soil is in a condition intermediate between the dry ground supporting the mixed deciduous forest and the low-lying wet ground where the moist forest occurs. The sal is found on well-drained situations with a good loamy soil,



FIG. 22. *Shorea robusta*, burnt *chandar* in April, showing dead sal shoots of previous year, and new leafy shoots of current year appearing, Pilibhit, United Provinces.



FIG. 23. *Shorea robusta* mature forest of good quality, high-level type, North Kheri forests, United Provinces. Undergrowth cleared for camping.

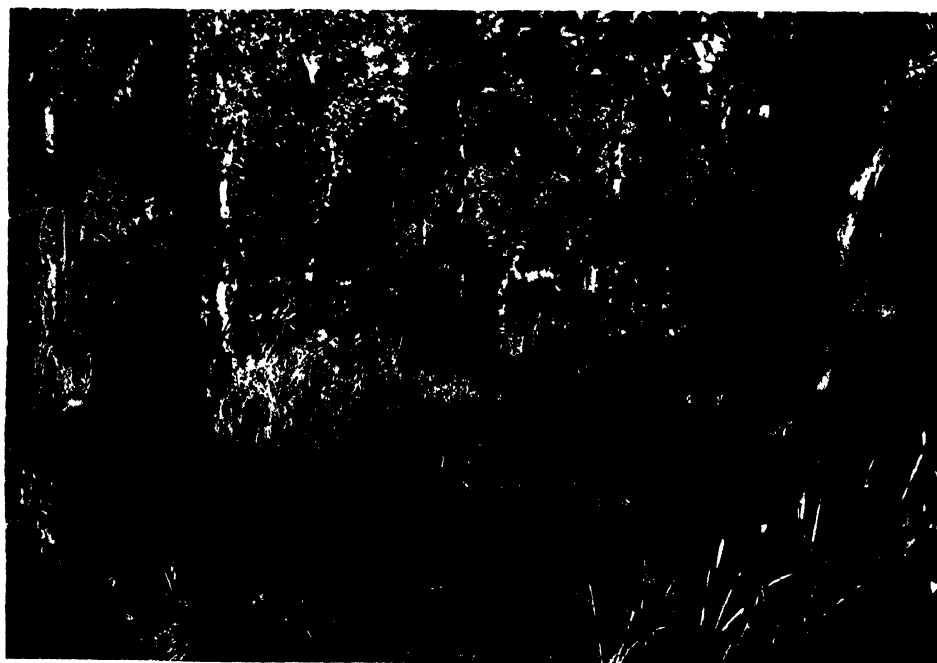


FIG. 24. *Shorea robusta* open forest, low-level type with soil-covering of grass, chiefly *Saccharum Narenga*, and no reproduction, Kheri Trans-Sarda forests, United Provinces.

elevated well above the level of the rivers and streams. Sal seedlings may sometimes be found in quantity in the mixed deciduous forests where soil conditions are favourable, and some of these forests are in process of being transformed into sal forests.

5. Forests of the *tarai* and plains. The *tarai* has been described above as the tract of springs, swamps, and streams fringing the outer edge of the waterless *bhabar* and separating it from the plains proper. The *tarai* country merges insensibly into the plains, and it is difficult to discriminate between *tarai* and plains sal forest, more especially as the water-level throughout the forests of these tracts is comparatively near the surface, and swamps and streams are plentiful. In what may be called the true *tarai* type of forest, which occurs in a belt at the outer edge of the *bhabar*, where springs, swamps, and deep streams are abundant, the sal does not occur on the low swampy ground, but on flat elevated plateaux about 15 to 20 ft. above it; these plateaux mark the original level of the country. The sal is of poor quality and rather stunted. Among its chief companions are *Mallotus philippinensis*, *Lagerstroemia parviflora*, *Stereospermum suaveolens*, *Terminalia tomentosa*, *Schleichera trijuga*, *Eugenia operculata*, and *Butea frondosa*. Climbers are sometimes plentiful, particularly *Bauhinia VahlIIi*, *Spatholobus Roxburghii*, and *Millettia auriculata*. In some parts of the *tarai*, especially where grazing has been heavy, the ground becomes hardened and much eroded, so that the plateaux become intersected by water-channels cut in the rainy season and dry throughout the rest of the year, with the result that broken or undulating country is produced. Here the sal forest is usually open and of very poor quality, as in some of the lower parts of the Jaspur forest near Ramnagar: a growth of *Imperata arundinacea* often covers the ground on the higher and more denuded parts, while *Saccharum Narenga* is confined to the more fertile depressions. Farther south towards the plains the sal forests, which are for all practical purposes confined to northern Oudh, are situated on flat alluvial ground with the subsoil water-level at a moderate depth. These forests are of great importance owing to their accessibility and their proximity to cultivated and populated tracts. The sal forests are not found on the lowest ground near rivers; this ground is occupied by the so-called low alluvial forests, consisting of *Acacia Catechu*, *Dalbergia Sissoo*, *Bombax malabaricum*, and other species, while in moist or swampy localities are found such moisture-loving species as *Eugenia Jambolana*, *Trewia nudiflora*, *Barringtonia acutangula*, *Salix tetrasperma*, and others. The sal forests are situated on older and higher alluvium, which is separated from the low alluvium by a well-marked bank, often 20 to 30 ft. high, locally known as a *damar*, representing the old bank of a neighbouring river, which may now be some miles distant. In some places this bank may have become much denuded or intersected by small ravines, and may thus have lost its sharp outline, but the difference in level between the sal forests and the low alluvium nevertheless exists. Apart from this difference in level, there are in some localities distinct differences in level within the sal forests themselves. This is particularly the case in the forests of North Kheri, where two distinct types of sal forest, the high-level and the low-level types, result from a difference in the level of the ground of about 10 ft. The line of separation between the high-level and low-level areas is

marked by a more or less distinct bank, which in places becomes little more than a gentle slope.

The configuration of the ground is further varied by broad shallow clayey depressions: the larger of these usually contain water throughout the year, and take the form of lakes or marshes, while the smaller ones may contain water only in the rainy season. Some of these depressions are mere water-logged grassy blanks within the forest: the sal avoids such places, which tend to fill up with *Terminalia tomentosa*, or in very moist places with *Barringtonia acutangula*. The country is drained by various streams and small rivers running through the forests, the water eventually reaching the Sarda (Gogra), Kauriala, Rapti, or Gandak rivers, and thence draining into the Ganges. In parts of their courses many of the forest streams have silted up in the past, and are now represented by elongated depressions covered with grass, and containing pools of water in places.

In the forests of Oudh the normal rainfall varies from 45 to 55 in., and the absolute maximum shade temperature varies from 110° to 115° F. In some localities, particularly in the Pilibhit and South Kheri forests, damage by frost in the winter is severe; in the North Kheri forests and in Bahraich frost damage is not serious in ordinary years, while in Gonda and Gorakhpur it is usually almost negligible.

The permanent subsoil water-level in the sal forests is never at a great depth. In the North Kheri forests in the cold season it varies ordinarily from 20 to 45 ft., and averages 35 ft. in the high-level forests, while in the low-level sal forests it varies from 13 to 23 ft. and averages 15 ft. The permanent cold weather water-level in the Gorakhpur sal forests is about 12 to 19 ft., in the Tikri forest, Gonda, it is about 15 ft., in the South Kheri forests about 20 to 30 ft., and in the Pilibhit forests about 10 to 15 ft.

The soil is entirely alluvial, but its constituents vary considerably even within comparatively narrow areas. During an investigation into the damage done to the sal forests of Oudh by the abnormal drought of 1907 and 1908 I had occasion in 1910 to have 39 wells dug down to water-level in the forests of Kheri, Pilibhit, Bahraich, Gonda, and Gorakhpur, with the view of examining the soil. In every case the surface soil to a depth of at least 2 ft., but usually more, consisted of sandy loam or clayey loam, while from water-level upwards for a thickness of at least 2 ft., but usually more, there was a deposit of pure sand: this deposit of pure sand frequently extended to more than half-way up from water-level to the surface, and in a few cases reached to within 5 ft. of the surface. Between the pure sand and the surface loam the soil consisted of layers of sandy or clayey loam, or of the two alternating; in exceptional cases there was a deposit of pure clay, sometimes 5 ft. or more in thickness. At or below water-level there was a deposit of clay, sometimes with concretionary calcareous nodules in it. The investigation referred to showed that the physical composition of the subsoil had a marked influence on the amount of damage done by the abnormal drought. The precise action of the drought is explained below (p. 89); it will be sufficient to note here that the damage was most severe in those localities where there was a thick deposit of pure sand in the subsoil. Apart from this, however, the composition of the subsoil evidently exercises a decided influence on the quality of the forest, as indicated

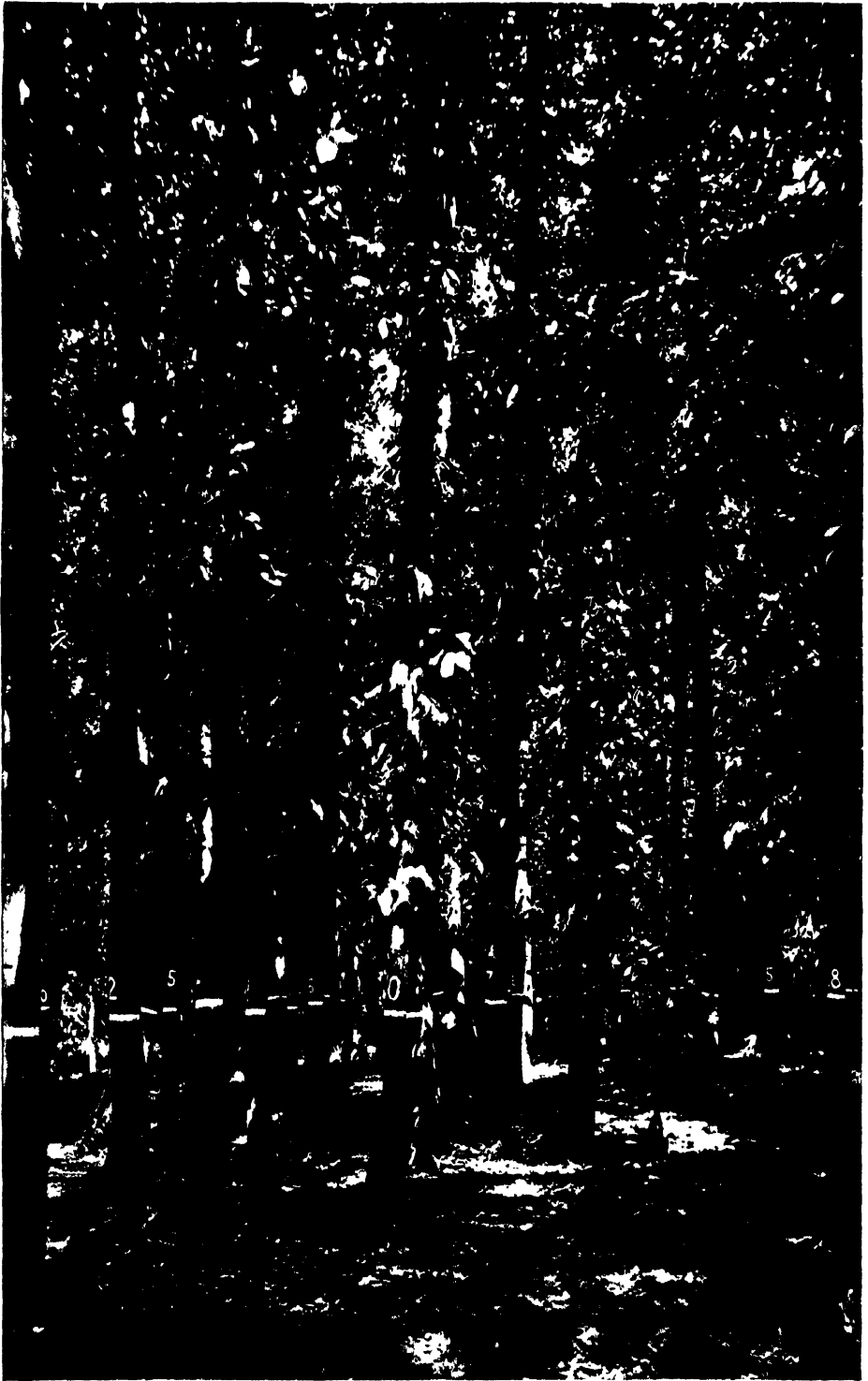


FIG. 25. *Shorea robusta* forest of *phanta*-belt type, showing absence of grass where stocking is dense, North Kheri forests, United Provinces.



FIG. 26. *Shorea robusta* poor open type of forest, Pilibhit, United Provinces.

by the height-growth. It has been suggested that the quality varies inversely with the depth of the subsoil water-level. It is certainly true that in the North Kheri high-level forests, which are on the whole of better quality than any other sal forests in Oudh, the water-level is at a greater depth than it is elsewhere, and there may be some reason for the assumption. At the same time this would not explain marked differences in the quality of the forest within short distances, the subsoil water-level remaining constant. The presence in the Gorakhpur forests of occasional patches of sal forest of very poor quality was noticed in 1913. In this type, which is shown in Fig. 20, the trees are stunted and often badly shaped, rarely exceeding 45 ft. in height, and the forest is usually rather open, with a soil-covering of grass; one of the most characteristic companions of the sal in this poor type of forest is *Eugenia operculata*. I had a well sunk down to water-level ($16\frac{1}{2}$ ft.) in the middle of one of these patches, and this revealed a subsoil totally different from that found in any of the 39 borings made in 1910, namely stiff clay from the surface all the way down to water-level, with only a slight admixture of sand at 8-11 ft., a 3 in. layer of sand at 15 ft., and a little sand at water-level. The poor quality of the forest was undoubtedly due to the stiff clay, causing bad aeration and drainage. Following on this, seven other wells were dug in forest of varying quality, with the general result that the poorer qualities were found in places where there was an excess of stiff clay in the subsoil, and the better qualities were found where the subsoil contained a considerable amount of sand and porous sandy loam.

The effect of a porous well-drained soil on the quality of the plains sal forests is further brought out by a fact noticeable in many localities, but particularly in the Gorakhpur forests, which are somewhat low-lying. Along the banks of streams running through the forests, some of which are now mere depressions, there are almost invariably strips of high ground varying from a few yards to a few hundred yards in width. These have been formed by the accumulated depositions of silt with the overflow of the streams in flood-time; the silt so deposited is coarser and therefore more porous than that which, in the form of fine clayey particles, is spread over the lower ground at a greater distance from the streams. The belt of forest on the high ground, with its porous soil, along either bank of the streams is always of distinctly better quality than the forest on the lower and stiffer ground away from the streams.

Subject to the variations in the configuration of the ground already noted, the sal forests of Oudh present the appearance of extensive stretches of flat forest country in which the sal is almost everywhere the dominant species, and in many places forms over 90 per cent. of the crop. The forests have been under fire-protection for many years. There is a complete system of broad fire-lines dividing the forests into convenient blocks and serving as road alignments; these fire-lines are a characteristic feature in the flat expanses of forest land. The forest tracts themselves are not unbroken stretches of woodland. They contain within their boundaries savannah lands, sometimes of large extent. These grassy tracts are particularly extensive in the North Kheri forests, where they are locally known as *phanta* lands; these are undoubtedly of artificial origin, and were at one time village lands under

cultivation. The dominant grass on them is *Saccharum Narenga*. Except in the low-lying parts they are eminently suitable for the growth of sal, and the sal is gradually encroaching on them round the edges of the forest or from clumps of seed-bearers scattered here and there over them. A different class of grassland is that known locally as a *chandar*, which is common in the Pilibhit and South Kheri forests. These *chandar* lands are subject to severe frosts, and are covered with a natural coppice growth of sal, the shoots of which are killed back year after year by frost, and never appear to make any progress except where specially sheltered or where the frost effects are mitigated by air circulation. The appearance of these *chandar* lands is shown in Figs. 21 and 22, and their origin is discussed below (p. 92). The dominant grasses on them are *Saccharum Narenga* on the higher and *Anthistiria gigantea* on the lower parts. The savannah lands, both *phanta* and *chandar*, are very inflammable, and it has been the custom to burn them annually during the cold season in order to prevent the spread of fire into the sal forests during the ensuing hot season. As a rule a fringe is left unburnt round their edges, with the view of encouraging sal reproduction to spring up and extend into the savannahs.

The types and qualities of sal forest met with on the plains of Oudh vary more than might be expected in a tract of country where the topographical features are at first sight not very pronounced. One of the most remarkable differences in type is seen in the North Kheri forests, where the high-level sal forests are of quite a different character from those on the low-level areas, although the difference in level between the two is only about 10 ft. In the high-level forests the growth is, on the whole, of better quality. Middle-sized trees are plentiful, and dense pole crops are common: everywhere masses of reproduction have filled up pre-existing gaps, and there are now practically no blanks. Fig. 23 shows a mature sal crop of fine quality in a high-level area. In the low-level sal forests much of the stock consists of mature trees in open crops, the ground being covered with much grass, chiefly *Saccharum Narenga*, and in places *Anthistiria gigantea* or *Imperata arundinacea* (see Fig. 24). Natural reproduction is more backward than in the high-level areas; in some places it is absent, but in many places it is making its way satisfactorily through the grass, sometimes with the aid of nurses such as *Holarrhena antidysenterica*, *Mallotus philippinensis*, and others. Here and there promising crops of sal saplings are establishing themselves, and in places there are dense pole crops in which the grass has been killed out. Throughout the greater part of the low-level areas the presence of so much inflammable grass is a constant source of danger, and when fires occur, as they do from time to time, much injury is done; the backwardness of reproduction in places may be attributed partly to the effects of fire.

A special and important type of forest in the low-level sal areas is that known as the *phanta*-belt type. It exists round the edges of the grassy blanks and represents former natural reproduction advancing into the savannahs. As a rule this belt varies from about 20 to 200 yds. in width. The crops are chiefly in the large pole stage; they are even-aged and are often of considerable density, in which case undergrowth is absent (Fig. 25), though a slight opening of the canopy produces a growth of grass, chiefly *Saccharum Narenga*. The trees are tall, straight, and well grown, and the sal is remarkably pure;



FIG. 27. *Shorea robusta* high-level forest of the Duars, with dense undergrowth of *sau* grass (*Pollinia ciliata*) and *Milletia auriculata* also plentiful. Buxa, Bengal.



FIG. 28. *Shorea robusta* dry deciduous type of forest in the bhabar tract of Goalpara, Assam.
Sal mixed chiefly with *Lagerstroemia parviflora*: appearance of forest in February.

a special feature is the almost entire absence of *Terminalia tomentosa* in the phanta-belt type.

The *damar*, or high bank separating the sal forests from the low alluvium, produces forest types of a particular kind, and the same applies to some extent to the less pronounced bank separating the high-level from the low-level sal forests. These banks are often much intersected by ravines, extending at times for a few hundred yards into the plateau and producing broken ground, the upper parts of which are much weathered and exposed to the desiccating influence of the sun. Here a poor dry open type of forest occurs, in which the sal is often mixed with *Diospyros tomentosa* : this type, which may be termed the upper *damar* type, appears to be commoner in Bahraich than in Kheri. It is most marked on stiff clayey soil, and is not found where the *damar* is not weathered or where the soil is porous and fertile ; in the latter case the good drainage often produces a specially good quality of forest along the top of the *damar*. Another type occurs in the depressions or miniature valleys of the broken country along the *damar*. Here the silt is washed down from the higher ground during the rainy season, and a moist fertile soil is produced. The result is that these depressions are occupied by sal forest of very fine quality. The fertility of the soil is indicated by a dense undergrowth, often of *Clerodendron infortunatum*, and numerous climbers encircle the trees. This may be called the lower *damar* type ; it is very limited in extent.

The good quality of the sal forests of North Kheri is perhaps most nearly approached by that of the Motipur forests of Bahraich, though both fall considerably short of the best qualities of forest in the Duars of Bengal and Assam. The South Kheri and Pilibhit forests are inferior in quality, though occasional good patches are met with, particularly in the northern parts of Pilibhit. Fig. 26 shows a poor open type of sal forest which is common in Pilibhit ; the poor growth is due mainly to the stiff badly-drained soil, but frost and drought are partly responsible for lack of vigour. In Gonda the plains forests are represented by the Tikri forest, an outlying block in which the quality is only moderate, though the accessibility of this tract gives it special importance ; this forest has been worked for many years as coppice-with-standards.

The Gorakhpur forests are, on the whole, only of moderate quality. The sal is, as a rule, remarkably pure : the height-growth is only moderate, though very fair growth is to be found along the high and well-drained ground in the neighbourhood of streams. Elsewhere the ground is somewhat low-lying, rice cultivation being practised in places up to the edge of the forest. The Gorakhpur forests are in the form of isolated blocks surrounded by cultivation. Their accessibility gives them a special value of their own, and in some of the blocks every stick, however small, is saleable. They lend themselves more than almost any other forests in India to an intensive system of management.

Bengal and Assam. In Bengal and Assam sal forests of a totally different type from those of the United Provinces are met with. The temperature is more equable, the rainfall greater and the humidity considerably higher. The absolute maximum shade temperature is only about 102° F. in the Duars ; the absolute minimum in the same tract is about 40° F., and in some of the sal regions of Assam it is probably higher. Frost is unknown in these regions.

In the sub-Himalayan tract of Bengal the normal rainfall varies from 130 to 200 in. Farther east, in Kamrup, Darrang, and Nowgong, it varies from 65 to 100 in., while in the Garo hills it varies from 82 to 126 in. In these regions the sal encounters conditions of humidity which not only produce different types of forest from those found elsewhere, but also create factors which influence the establishment of natural reproduction in a different way. In the sub-Himalayan tract of Bengal and Assam the sal may be said to be growing under optimum conditions. Seedlings if grown in the open do not die back, but shoot up rapidly from the start. The subsequent growth of the trees is faster than in the western sub-Himalayan tract or in the central Indian region, and the quality of the sal forest is unequalled elsewhere, except perhaps in the valley type of the Singhbhum sal forests. In parts of the sub-Himalayan tract of the United Provinces the sal certainly attains large dimensions, but nowhere are there extensive tracts of sal forest, as in Bengal and Assam, where trees of such excellent height-growth are met with or where soundness is maintained to such a marked extent in trees of large size.

In western Bengal the sal is found in the Kurseong *tarai* and on the lower slopes of the hills up to 3,000 ft., ascending the Tista valley for some distance. The quality of the forest is, as a rule, excellent, the trees reaching large dimensions. As in the Duars, the dense undergrowth and the unfavourable soil conditions due to the excessive damp interfere with the natural reproduction of the sal. East of the Kurseong *tarai* the sal occurs throughout the Duars tract of Jalpaiguri, Buxa, and Goalpara, described in detail below, ascending the river valleys and the outer hills to about 3,000 ft. Thence the sal extends eastward, in suitable localities, through Kamrup, Darrang, and Nowgong. In Darrang the sal is at its eastern limit, and the total area of sal forest amounts to only about 700 acres, the best patch being in the Gorumari reserve, where the growth is good. Among the chief associates of the sal in Darrang are *Eugenia lanceaefolia*, *Gmelina arborea*, *Phyllanthus Emblica*, *Litsaea polyantha*, *Schima Wallichii*, *Stereospermum chelonoides*, *Sterculia villosa*, *Careya arborea*, *Adina cordifolia*, *Cinnamomum Cecidodaphne*, and *Bridelia retusa*.

In the Assam sal forests in general, as in the Duars, natural reproduction is a matter of difficulty, owing to the excessive damp, and the sal is likely to disappear in many places if special steps are not taken to regenerate it. In the Garo hills the sal attains very large dimensions, but the forests have suffered much from shifting cultivation. The same agency has destroyed much of the sal in the Khasi and Jaintia hills.

One of the most important sal tracts of the eastern sub-Himalayan region is that known as the Duars, occupying a stretch of country about 150 miles long, between the Tista and Manas rivers, with a maximum width of about 30 miles from the base of the hills southwards into the plains. The western or Bengal Duars, containing the Jalpaiguri and Buxa forests, lie west of the Sankos river, and the eastern Duars, containing the Goalpara forests of Assam, lie east of it. Sal occurs in the outer hills mixed with other species, but in the Duars proper two broad types of sal forest may be distinguished—the high-level or dry type, and the low-level or moist type. The high-level or dry type, which occurs in Buxa and Goalpara, occupies the dry *bhabar* tract on deep

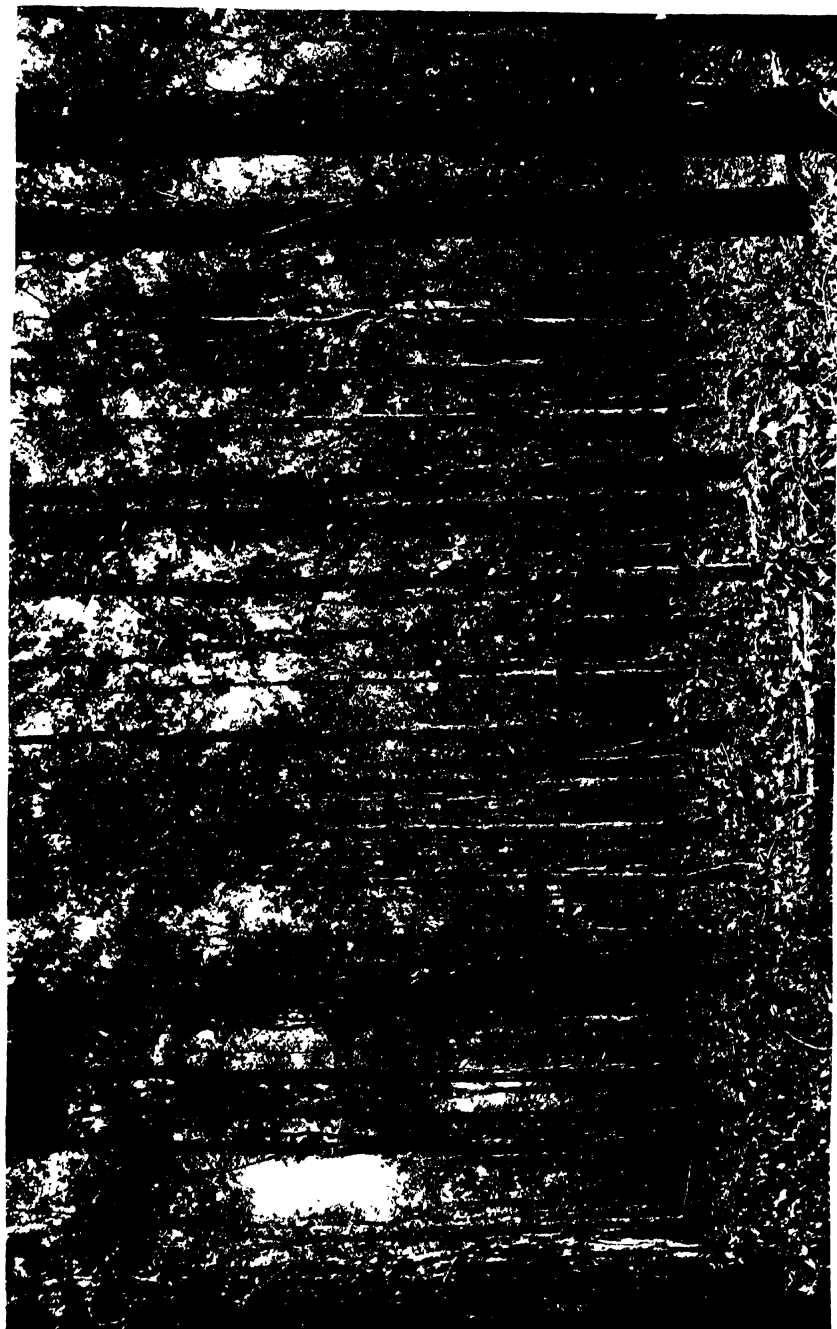


FIG. 29. *Shorea robusta* forest of best quality, just thinned, Jalpaiguri, Bengal. Mean girth 2 ft. 3 in. ; mean height 100 ft. ; stems per acre after thinning 156 ; volume of standing crop 3,764 cub. ft. ; volume removed in recent thinning 765 cub. ft. ; estimated age 60 years.



FIG. 30. *Shorea robusta* low-level forest of good quality, with fire-line, Goalpara. Assam.

boulder and gravel deposits stretching from the base of the hills to a maximum distance of about 12 miles from them: here the water-level is at a great depth. In Jalpaiguri this type is scarcely represented. The sal is, as a rule, of excellent quality. Among its commoner associates are *Lagerstroemia parviflora*, *Terminalia belerica*, *Sterculia villosa*, *Bombax malabaricum*, *Dillenia pentagyna*, *Cedrela Toona*, *Albizzia procera*, *Gmelina arborea*, *Stereospermum suaveolens*, *S. chelonoides*, *Premna* spp., and *Bauhinia* spp. The characteristic soil-covering is a dense growth of *sau* grass, *Pollinia ciliata*, Trin., a light feathery grass with a thin straggling wiry stem, which grows ordinarily to a height of 2 or 3 ft., but may climb through light undergrowth to a height of 5 or 6 ft., forming a dense mass which prevents sal seed from reaching the ground. This grass, which also occurs in the low-level type, though it is less abundant there, stands moderate shade, but is killed out by dense shade; it is encouraged by fire-protection. With it is commonly found an undergrowth of *Millettia auriculata*. Fig. 27 gives some idea of a typical *sau* grass area. Natural reproduction of sal in these areas is present only where the grass is scanty or absent. A dry and markedly deciduous sub-type of the high level forests occurs very locally in Goalpara. In this sub-type the sal reaches only moderate size, and its chief companions are *Lagerstroemia parviflora*, *Terminalia Chebula*, and *Phyllanthus Emblica*. The undergrowth either is absent or consists of a somewhat light growth of *Millettia auriculata*, *Dalbergia stipulacea*, and sometimes *Coffea bengalensis*; there is often present a scanty growth of grass, usually *Triraphis madagascariensis* var. *Zollingeri*, a grass ordinarily characteristic of dry miscellaneous forest. In this dry sub-type, which is shown in Fig. 28, natural reproduction of sal is usually good in spite of, and possibly in consequence of, fire-protection, a circumstance which is at variance with the conditions prevailing throughout the Duars sal forests as a whole.

The low-level or moist type of sal forest commences along the line of springs marking the southern limit of the dry *bhabar* tract. The forest is of a moist type, with a luxuriant and often evergreen undergrowth. The subsoil water-level is usually at no great depth. This type produces trees of large size and good shape where the drainage is good: in Goalpara particularly there are occasional patches of sal on badly-drained ground, where the growth is decidedly inferior. In Jalpaiguri the forest is of a moist type throughout, and on the well-drained high ground not far from streams the quality is extremely good, the boles being tall and cylindrical (see Fig. 29). Fig. 30 gives a typical view down a fire-line running through the Goalpara low-level sal forests. Most of the companions of the sal which occur in the dry or high-level type occur also in the moist type, but there is present a larger proportion of evergreen trees, such as *Amoora*, *Meliosma*, *Turpinia*, *Michelia Champaca*, *Schima Wallichii*, *Machilus*, and other lauraceous trees. There is a dense and largely evergreen undergrowth, which is described below.

The forests of the Duars, more particularly those of the moist type, furnish a striking example of the effects of continued fire-protection in altering the character of the forest and bringing it into such a condition as entirely to prevent the natural reproduction of the sal. It is an indisputable fact that the existing sal forests had their origin in burnt savannah lands. This is

borne out from observations in burnt savannahs at the present day as well as from authentic records contained in forest working plans. The savannah lands are a characteristic feature of the Duars, particularly in Goalpara and Buxa; in Jalpaiguri they have now for the most part become filled up by tree-growth. Two broad types of savannahs may be distinguished, the low-level and the high-level savannahs. The former occupy low-lying moist ground containing a dense growth of such grasses as *Phragmites Karka*, Trin. (*narkal*), *Saccharum procerum*, Roxb. (*ekra*), *Erianthus elephantinus*, Hook. f., *Anthistiria gigantea*, Cav., *Saccharum spontaneum*, Linn., and others. On these tracts are scattered trees, chiefly *Albizzia procera*, *Bombax malabaricum*, *Bischoffia javanica*, *Eugenia operculata*, and *Butea frondosa*. In the riverain alluvial savannahs *Dalbergia Sissoo* is dominant. The low-level savannahs are unsuitable for the growth of sal. The high-level savannahs are typical sal-producing tracts, and occupy the better drained lands. The dominant grass of these tracts is *Saccharum Narenga*, Wall. (*bata*), which indicates conditions favourable for sal reproduction and growth. Other grasses on the high-level savannahs are *Saccharum arundinaceum*, Retz., *Arundinella Clarkei*, Hook., *Erianthus fastigiatus*, Nees, *Andropogon Nardus*, Linn., and *Imperata arundinacea*, Cyrill.; on ground sometimes not sufficiently well drained for sal occur *Saccharum spontaneum* and *Anthistiria gigantea*. The origin of the savannahs is not always clear, but there is no doubt that many of the high-level savannahs are the result of former clearings for cultivation; this is shown from the fact that former village sites, and bunds and boundaries of fields, are often still visible, while at the present time abandoned fields at once revert to savannah.

The savannahs become very dry by February, and if not specially fire-protected they burn at that time of year, producing fires of great severity. As long as annual fires occur these tracts persist in the form of grass-lands subject to the gradual invasion of fire-resisting trees such as sal, *Careya arborea*, *Dillenia pentagyna*, *Eugenia operculata*, *Bombax malabaricum*, and a few others. The establishment of the sal under these conditions is, it is true, gradual, seedlings and saplings being destroyed in quantity by the severe fires. Eventually, however, natural reproduction establishes itself by degrees, particularly where the saplings appear in clumps and commence to kill off the grass. Figs. 31, 32, and 33 show the manner in which the sal forests originate in these tracts.

Fire-protection was commenced in the Duars in 1872, and has been extended gradually since then. When a burnt savannah is fire-protected certain invasive trees and other plants quickly make their appearance. Of these the most characteristic is *Macaranga denticulata*, which is referred to below (p. 100). *Trema orientalis* and *Callicarpa arborea* are also forerunners of the subsequent tree forest, while the scitamineous plant *Alpinia Allughas* spreads rapidly. Where sal existed in quantity on the burnt savannah a more or less pure sal forest results, otherwise various deciduous trees and shrubs, such as *Sterculia villosa*, *Litsaea polyantha*, *Terminalia belerica*, *Gmelina arborea*, *Bombax malabaricum*, *Cedrela Toona*, *Lagerstroemia parviflora*, *Dillenia pentagyna*, *Careya arborea*, and many others, soon fill the gaps, the savannah grass is gradually killed out, and the result is a mixed deciduous forest, often with



FIG. 31. Burnt savannah with young sal (*Shorea robusta*) gradually establishing itself in spite of fire, Goalpara, Assam; the grass is *Saccharum Naranga*, recently burnt.



FIG. 32. *Shorea robusta*, young growth established in savannah burnt annually. Buxa, Bengal ;
the grass is *Saccharum Naraya*, not yet burnt.

patches of sal in it. This, however, is only a stage in the progressive succession towards forest of a moister and more evergreen type. Wherever there is sufficient moisture *Alpinia Allughas* becomes invasive and forms dense masses, while *A. bracteata* appears in moist shady places (see Fig. 34). Species of *Leea*, *Vitis*, *Piper*, and other trailers and shrubs, together with ferns, make their appearance in quantity and form a dense soil-covering, above which appear masses of shrubs such as *Phlogacanthus thyrsiflorus*, *Viburnum Colebrookianum*, *Casearia Vareca*, *Micromelium pubescens*, and others (see Fig. 35). Evergreen shade-bearing trees such as *Amoora*, *Meliosma*, *Turpinia*, various Lauraceae, and others, commence to form a lower story, the larger species penetrating to the upper story. The whole mass is cemented together by a luxuriant growth of climbers such as *Spatholobus Roxburghii*, *Croton caudatus*, *Mucuna macrocarpa*, *Millettia auriculata*, *Mezoneuron cucullatum*, *Acacia Intsia* and *concinna*, *Bridelia stipularis*, and many others, while the damper places are often covered with a dense impenetrable mass of climbing and scrambling canes (see Fig. 36).

Such is the state to which the sal forests of the Duars, which originated in burnt savannah lands, in some cases possibly with an intervening stage of burnt deciduous forest, have been brought after a period of some thirty to forty years of fire-protection. A condition has been reached in which, as will be explained below, the establishment of natural reproduction of sal is out of the question, and the future of the species can be secured only by clear-felling followed by artificial reproduction.

Bihar and Orissa. In the sub-Himalayan tract of Bihar there are no regularly administered state forests. Mr. Haines¹ has given an interesting account of the forests of northern Champaran, in which he mentions that the greater part of the northern boundary of British territory borders the Nepal *tarai* at a considerable distance from the hills, but in the extreme north-west it recedes and is carried along a range of low hills in the north of the Ramnagar and Bettiah estates. These hills, with a strip of submontane land, are still covered with forest, while there is also a tract of forest, one to three miles wide, along the Gandak river in Bettiah, and a strip along the Nepal boundary to the east.

The forests are chiefly sal forests, intersected by strips of mixed forest on the newer alluvium and in the damper valleys. The sal attains its best growth in the *bhabar* at the foot of the hills, on the high banks of the older river valleys, and in the valleys themselves. In some of the more shady sal forests there is a gregarious growth of *Croton oblongifolius* on the ground. On the higher ground of the *bhabar* and on the hills the height-growth of the sal is usually poor; in these localities *Dillenia aurea* is a characteristic tree. On the hill ridges, at 1,000 to 1,600 ft., the sal is associated with *Pinus longifolia*. The hills themselves belong to the Siwalik system, and consist of fine-grained sandstone interbedded with occasional layers of water-worn stones. The sal forests have suffered from over-felling and from fire, while grazing further tends to keep down reproduction.

South of the Ganges the sal tracts of Bihar and Orissa lie mainly in the forest divisions of the Santal Parganas, Palmau, Chaibassa, Singhbhum,

¹ Ind. Forester, xliii (1917), p. 245.

Porahat, Sambalpur, Angul, and Puri. There are also considerable tracts in the Orissa Feudatory States.

The district forests of Hazaribagh contain a fairly large extent of sal, but they have suffered from all kinds of misuse in the past, and there are few trees of any size left. The sal forests of Palamau and Hazaribagh are somewhat poor in quality, being situated for the most part on shallow or unfertile soil. The rainfall varies from 40 to 54 in., but in the hot weather months the forests have to endure a high temperature and a low humidity owing to the prevalence of hot dry westerly winds from central India. In the winter frost damage is severe in places. In the Santal Parganas the sal is, on the whole, of better quality than in Palamau and Hazaribagh.

The forests of Sambalpur have suffered in the past from fire and resin-tapping, and large trees are mainly unsound and misshapen; former shifting cultivation has also created many blanks. The forests improve in quality towards the south. The chief companions of the sal are *Terminalia tomentosa*, *Pterocarpus Marsupium*, *Anogeissus latifolia*, *Diospyros Melanoxyton*, *Bassia latifolia*, *Dalbergia latifolia*, *Buchanania latifolia*, and *Eugenia Jambolana*; bamboos (*Dendrocalamus strictus*) are common in some of the poorer types of sal forest in hilly country. The sal is found chiefly in the valleys and on the lower slopes of hills, the upper and drier parts of which are covered with dry mixed forest or bamboos. The rock consists chiefly of sandstone, quartzite, shale, mica schist, and laterite. The rainfall averages about 56 in.

In Angul sal occupies the greater part of the reserved forests in the south and west of the district. Its density increases and its growth improves on proceeding from west to east. Trees of large size are not common, the stock being represented mainly by an advance growth of seedlings and saplings. In the high-lying valleys, at an elevation of about 1,100 to 1,500 ft., the growth is good, but in the low-lying valleys and plains the conditions are less favourable. Among the chief companions of the sal are *Pterocarpus Marsupium*, *Dalbergia latifolia*, *Ougeinia dalbergioides*, *Terminalia tomentosa*, *T. belerica*, *Adina cordifolia*, *Lagerstroemia parviflora*, *Anogeissus latifolia*, and *Stereospermum suaveolens*. The rock is chiefly gneiss and quartzite. The normal rainfall is about 50 to 55 in.

In Puri the northern and central forests, which are mainly on sandstone and laterite, consist for the most part of coppice growth varying from poor mixed forest to well-stocked forest of sal and *Xylia xylocarpa* poles. In the southern forests, which are for the most part on gneiss, giving a deep sandy loam in the valleys and on the lower slopes, the locality is much more favourable, and is capable of producing large-sized timber. The rainfall in the forest tracts varies from 50 to 60 in.

The forests of Singhbhum comprise by far the most important sal tracts in the province. The forest division of Singhbhum at one time included the forests of Kolhan and of the Porahat estate, but these have now been constituted separate divisions. A considerable portion of the Kolhan forests are on rather poor hilly ground, where the sal does not reach large dimensions, but towards the south-west they improve in quality and approach the type found in Singhbhum. The Porahat forests are likewise drier in type than those of Singhbhum, although in the valleys and on lower slopes they contain



FIG. 33. *Shorea robusta*, pole crop established in burnt savannah, Goalpara, Assam; the grass is chiefly *Saccharum Narenga*, recently burnt.



FIG. 34. *Shorea robusta* forest with invasive evergreen undergrowth, chiefly *Alpinia*, induced by continued fire-protection, Jalpaiguri, Bengal.

sal forest of decidedly good quality. The forests of Singhbhum proper, which are known as the Saranda forests, are situated in mountainous country at an elevation of 750 to 3,000 ft. The rocks are chiefly sub-metamorphic, consisting for the most part of quartzites, ferruginous schists, siliceous slates, and shales, while laterite is not uncommon. The rainfall varies from 50 to 65 in. Frost is very local in some of the high-lying plateaux, but the damage done by it is seldom severe. The quality of the forest varies greatly. In the valleys the forest is moist and the growth is excellent, the trees often reaching a height of 120 ft. On the hills a drier type of forest is met with in which the growth is poorer. On the drier ridges an open type of sal forest is common, in which the trees are stunted, misshapen, and often hollow. The poorest type of all is found on argillaceous rocks decomposing into a hard clay with quartz pebbles on the surface. The sal, if present, is very stunted, and is usually associated with *Gardenia gummifera*, *Buchanania latifolia*, *Terminalia tomentosa*, *Anogeissus latifolia*, and *Diospyros Melanoxydon*, while *Phoenix acaulis* frequently covers the ground. In the dry open types of hill forest the prevailing grass is the *sabai* (*Ischaemum angustifolium*, Hack.), which constitutes a valuable source of minor produce. Between the poorer hill types and the moist valley type there are various intermediate types occupying the hill-slopes and plateaux, and in all except the drier hill types the growth of the sal is decidedly good. A special feature of the Singhbhum sal forests is the excellence of the natural reproduction, which has established itself in profusion, particularly where heavy fellings were carried out from 1895 onwards.

Among the commonest companions of the sal are *Terminalia tomentosa*, *Pterocarpus Marsupium*, *Ougeinia dalbergioides*, *Bassia latifolia*, *Lagerstroemia parviflora*, *Adina cordifolia*, *Anogeissus latifolia*, *Buchanania latifolia*, and *Bauhinia retusa*.

Central India. There are considerable areas of sal forest to the south of the Kymore hills in Rewah state, but these have suffered a good deal from past felling and from resin-tapping.

Central Provinces. The important sal tracts of the Central Provinces are situated in the Jubbulpur, Mandla, Balaghat, Bilaspur, and Raipur districts. The Jubbulpur district is interesting in being the meeting-place of several geological formations. The existence of the sal, which is here at its western limit in the Peninsular region, is determined by the porous but hygroscopic Gondwana earthy sandstone, to which it is practically confined, and by the favourable rainfall, which is about 50 to 55 in. in the sal areas; teak, on the other hand, is confined to the trap and Vindhyan areas, chiefly sandstones, where the drainage is good. The sal is not of good quality, mature trees averaging scarcely 60 ft. in height, with a maximum height of 80 ft.; they seldom attain more than 5 ft. in girth, and are then usually unsound. Frost damage is severe in the cold weather, while in the hot season the temperature may reach 114° F. in the shade. Natural reproduction suffers much from frost.

In the Mandla district the sal forests of the Banjar valley are situated for the most part on the lower slopes of hills or in high valleys, chiefly at 1,800 to 2,000 ft., the hills being covered with mixed forest and the low ground being occupied by grass-lands. The quality of the sal forest varies. In

favourable localities the growth is good, trees exceptionally attaining a height of 120 ft. and a girth of over 10 ft. : in poor localities they are stunted. The Motinala forests are much intersected by the remains of former shifting cultivation. The sal avoids the low ground, which is occupied by grass-lands. Frost does much damage, killing back sal reproduction. In the Khannat sal forests of South Mandla the quality varies much from place to place, but is on the whole inferior to that of the Banjar and Motinala forests. They are situated on laterite or on soil composed of a mixture of laterite and trap ; the sal avoids pure trap areas. On the slopes of the hills much of the sal forest originated in former temporary cultivation, and even-aged crops of poles, partly of seedling and partly of coppice origin, are the result. On the flat hill-tops with shallow soil a stunted type of sal forest is found. Among the chief companions of the sal in Mandla are *Terminalia tomentosa*, *Ougeinia dalbergioides*, *Pterocarpus Marsupium*, *Lagerstroemia parviflora*, *Anogeissus latifolia*, *Adina cordifolia*, *Stereospermum suaveolens*, and *Buchanania latifolia*. The rainfall varies from 50 to 60 in.

In the Balaghat district there are two main sal areas, Raigarh and Baihar. In the former the rock consists of laterite and trap, but the sal avoids the pure trap ; in the latter the rock is largely gneiss. The sal occurs on low hills, on the lower slopes of high hills, and on the undulating portions of valleys. In Raigarh it occurs chiefly at an elevation of 2,000 to 2,500 ft., the lower ground being occupied by grass-lands. In Baihar the upper limit of the sal is 2,000 ft., and the sal forest is much interspersed with grass-lands. The sal is almost pure except where it merges into mixed forest, in which case it forms only a small portion of the stock : in Baihar it is frequently mixed with bamboos (*Dendrocalamus strictus*). The sal forest varies much in quality, but in favourable localities trees of large size are produced. In some localities frost damage is severe, young sal being killed back annually and poles also suffering much. The rainfall varies from 50 to 65 in.

In Bilaspur the most important sal forests are those of Lormi, Kanhai, and Shirmal. In Lormi the best sal is found in the valleys and on the lower slopes of the hills : the principal rocks of the sal areas are schists of the Dharwar series. The best sal trees are often found mixed with large *Terminalia tomentosa* on deep moist alluvial soil near some of the rivers. A type occurring along the base of the hills consists of a good crop of fair-sized sal standing over a dense crop of bamboos, which retard sal reproduction. The Kanhai sal forests are somewhat similar to those of Lormi. The Shirmal sal forests produce timber of moderate size, but not so large on the whole as in Lormi. In the Bilaspur sal forests frost damage is often severe. The rainfall is about 50 in. Sal also occurs in the Chita-Pandaria forests on shallow soil overlying limestone ; it is found only in small quantities, however, and the growth is poor. The Sonakhan sal forests in the north of the Raipur district are included in the Bilaspur forest division. They are situated on metamorphic and sub-metamorphic rocks, ceasing abruptly at the Cuddapah sandstone belt and avoiding limestone.

In the Raipur district the Sihawa forests constitute a promising tract of sal, although the trees are as yet immature. In the northern part of the tract sal occurs only in scattered patches, but farther south it increases in



FIG. 35. *Shorea robusta* forest with invasive evergreen undergrowth, chiefly *Phlogacanthus thyrsoiflorus*, induced by continued fire-protection. Jalpaiguri. Bengal.



FIG. 36. *Shorea robusta*, forest with invasive evergreen undergrowth, largely of canes
in the National Geo. Botanical Garden, Jalpaiguri, Bengal.

quantity, and forms large pure masses. The rainfall is slightly over 50 in. Sal forests also occur in the south-east of the Laun range, the best of them being in the Kantranala reserve: elsewhere the sal is found in straggling belts and patches or in the form of isolated trees in dry forest. Both the Sihawa and the Laun sal forests are found on metamorphic rocks.

Madras. In the Madras Presidency sal occurs chiefly in Ganjam, and to a limited extent in Jeypore and in the Palkonda range of Vizāgapatam. In the Ganjam district sal is found in the Goomsur forests. The rock is largely gneiss, with metamorphosed sandstone in places. An indurated ferruginous red clay caps many of the low hills, and the sal growth here is poor, the soil being not sufficiently porous. In the western part of the Goomsur forests (Surada range) the country is chiefly hilly, the sal occupying the slopes of the hills and growing to a very fair size in favourable localities. To the east (Buguda range) the country is flatter, and the sal grows at a lower elevation on the whole. In the forests of the plains, on alluvial ground, the sal is purer but of smaller size than in the hill forests. The plains forests have been subjected to much ill treatment in the past, and the stock consists largely of coppice and pollard growth. The chief companions of the sal are *Terminalia tomentosa*, *Pterocarpus Marsupium*, *Lagerstroemia parvifolia*, *Dalbergia latifolia*, *Adina cordifolia*, and *Diospyros Melanoxydon*. Where the soil becomes less favourable there is a larger mixture of *Cleistanthus collinus*, *Soymida febrifuga*, *Dillenia pentagyna*, *Buchanania latifolia*, *Phyllanthus Emblica*, and *Odinia Wodier*. In Ganjam the sal experiences the north-east as well as the south-west monsoon. The rainfall is about 50 in., of which the south-west monsoon, July to September, contributes 30 in., and the north-east monsoon, October to December, 15 in., the remaining 5 in. falling from January to June.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The leaves commence turning yellow and falling from January to March. In dry seasons and in dry localities leaf-shedding takes place earlier and is more complete than in wet seasons and in moist localities; in the latter the leaves may have hardly commenced to fall by March. For a short time, from February to April, according to locality and season, the foliage of the trees is somewhat scanty: only in dry localities, however, do the trees become quite leafless for a short time. The new leaves and shoots appear from February to May according to locality and season. The young leaves are tender, reddish, and shining: they soon turn to a fresh delicate green. Where the old foliage is defoliated by insects early in the year the new shoots appear earlier than usual. Sometimes two separate flushes of new leaves appear in one season. A second flush may appear after defoliation, but it may also be produced in exceptionally dry seasons after a partial shedding of the first flush.

The flower-buds as a rule first become visible in February, but in early seasons they may appear in the latter part of January. The small whitish flowers are in large lax terminal or axillary racemose panicles, covered with a whitish pubescence (see Fig. 37). They are fully out from the end of February to well on in April, according to locality and season. At this time the trees are partially leafless, and when covered with masses of whitish blossom they are a striking sight, particularly in years of extensive and profuse flowering, when the whole forest is clothed in a mantle of white. Fig. 39

shows a sal tree in flower. The petals soon fall like snow, covering the ground beneath and around the trees.

The young fruits form rapidly, and their reddish to pale yellowish-green colour gives a characteristic hue to those trees which bear them in quantity. The fruits (Figs. 38 and 40, *a*) are 0.5–0.6 in. long by 0.4 in. in diameter, ovoid, acute, whitish pubescent, indehiscent, surrounded by the segments of the calyx enlarged into five rather unequal wings which are 2–3 in. long, obtuse, spatulate, contracted at the base, brown when dry. About 350–420 fruits weigh 1 lb. The fruits ripen in June, and fall as soon as they ripen; ordinary breezes do not carry them more than about 50 to 100 yards from the tree, but strong winds may convey them to a considerable distance. If moisture conditions are favourable the seed germinates soon after falling, and germination may even begin on the tree. Sound fresh seed has a high percentage of fertility, but the seed rapidly loses its vitality, and under ordinary conditions will not keep fertile for many days. Drought is the chief cause of mortality, and if care is taken to keep the seeds cool and prevent their dying they may retain their vitality for a few weeks. Seed sent by Mr. Hole from Dehra Dun to Singapore, which was twenty-four days in transit, produced a good stock of healthy seedlings. An experiment was carried out at Dehra Dun in 1913 to ascertain the length of time during which seed would remain fertile if kept under different conditions. Fresh seed gave a fertility of 90 per cent., and seed from the same sample stored under different conditions gave the following results:

Shorea robusta: germination tests of seed kept under different conditions.

Percentage of fertility under different methods of storage.

Number of days after collection.	Loose in	Loose in	Packed in	Packed in	Packed in
	basket indoors.	basket in shade out of doors.	dry earth.	sawdust.	lime.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
7	50	90	50	55	90
15	10	25	25	50	40
20	10	nil	30	40	40
27	nil	nil	5	nil	45

Sawdust was found to check germination, but lime did not have this effect, the seed germinating and producing taproots 3 in. long and shoots 2 in. long, though the young plants kept in perfectly good condition in the lime, some remaining so for two months or more. Lime would thus appear to be a suitable medium for packing seed to send to a distance.

A note¹ which I published in 1912 gave the results of a large number of germination tests carried out in different localities, the main object of which was to ascertain to what extent the fertility of sal seed is affected by the size and condition of the trees producing it and by the locality and the type and density of forest in which the trees grow; the question is of importance in connexion with the retention of seed-bearers. The quantity of seed produced under different conditions was not a subject of investigation. The chief results obtained were as follows:

(a) The size of the tree has no apparent effect on the fertility of the seed.

¹ Note on some Germination Tests with Sal Seed, For. Bull. No. 8, 1912.



FIG. 37. *Shorea robusta* flowers. Squares show inches and decimals.



FIG. 38. *Shorea robusta* fruits. Squares show inches and decimals.



FIG. 39. *Shorea robusta* tree in flower.

(b) In some localities fertile seed begins to be produced by trees under $1\frac{1}{2}$ ft. in girth, the minimum girth recorded being 7 in. ; in other localities no seed was obtainable from trees of this size.

(c) The average percentage of fertility is maintained in trees of large girth, namely, 15 ft. and over.

(d) Factors which were not proved to have any effect on the fertility of the seed were (i) the soundness or unsoundness of the seed-bearers, and (ii) the locality, soil, aspect, and type and density of forest in which the seed-bearers grow.

(e) The time of collection possibly has an influence on the fertility of sal seed, the most fertile seed being obtained at the middle of the fruiting period and less fertile seed being obtained at its beginning and end ; further experiments, however, are necessary before any definite conclusion can be arrived at on this point.

As regards the size of the trees which produce fertile seed, it may be noted further that in 1910, a favourable seed-year in the Dehra Dun forests, abundant seedlings were observed to have sprung up round pole forest where the largest trees were not more than 2 ft. in girth and 40 ft. in height. In the dry stunted forests of the Siwalik hills numerous seedlings were found where none of the seed-bearers exceeded 22 in. in girth.

The fertility of seed from coppice-shoots was at one time called in question. All doubt on the subject, however, has been set at rest by tests carried out in different localities. A series of experiments carried out in 1905 and previous years in Bahraich, United Provinces, showed that seed from coppice germinates well ; in some cases there was no appreciable difference between its fertility and that of seed from seedling trees, while in other cases seed from seedling trees gave better results than that from coppice-shoots. Tests carried out in 1906 in Gonda, United Provinces, with seed from coppice-shoots of various sizes showed an average fertility of 70 per cent. Mr. C. E. C. Fischer¹ has recorded the results of germination tests in Ganjam, Madras, in which 170 seeds each were tested from coppice-shoots and standards. The result showed a fertility of 40 per cent. for the seed from coppice-shoots as against 48 per cent. for seed from standards : there was no difference in the vigour of the resulting seedlings.

In most localities good seed-years are of fairly frequent occurrence, while occasionally the seeding is remarkably gregarious and profuse. When storms, hail, or strong dry winds occur from March to June the flowers and immature fruits, whose peduncles are very tender, may be blown or knocked down in quantity, and an otherwise promising seed-crop may be entirely destroyed. Insects are at times also responsible for the destruction of a good deal of seed. The statement on p. 80, showing the nature of the seed-year in different localities and years, has been compiled from such records as exist : these are not always very accurate or precise, but the statement may be taken as approximately correct on the whole.

¹ Ind. Forester, xxx (1904), p. 198.

Shorea robusta : records of seed-years in different localities.

United Provinces.										Bengal.										Assam.					Bihar and Orissa.				



FIG. 40. *Shorea robusta*—SEEDLING $\times \frac{3}{8}$

a—Fruit b - e —(Germination stages (d shows cotyledons detached from fruit)
 f - h —Development of seedling during first season

The foregoing statement shows in a remarkable manner how widespread a good or a bad seed-year may be in certain years. In the United Provinces the year 1910, and throughout the greater part of the sub-Himalayan tract the years 1913 and 1915, will be remembered as years of profuse seeding, while in the intermediate years the seed-crop was a failure. Apart from injury to the seed-crop by storms and winds, climatic conditions appear to be responsible at times for the state of the seed-year. In the spring of 1905 the forests of the United Provinces were much damaged by an abnormally severe frost, and the failure of the seed-crop was reported at the time to be due to this cause. The year 1908 in the United Provinces, and the year 1916 in Bihar and Orissa, in which the seed-crops failed, followed seasons of abnormal drought.

GERMINATION (Fig. 40, *b-e*). Hypogeous. The radicle emerges towards the apex of the fruit and descends rapidly, soon forming a taproot. The cotyledonary petioles meanwhile elongate considerably, carrying the plumule free of the seed and enabling the young shoot to make its way upwards. The fleshy cotyledons remain within the fruit.

THE SEEDLING (Fig. 40).

Roots : primary root long, thick, terete, tapering, woody : lateral roots fibrous, long and numerous if growing in water or in moist layers of dead leaves, shorter and less numerous in mineral soil. *Hypocotyl* scarcely distinguishable from root, subterranean. *Cotyledons* appearing to be opposite, but shown by the position of the axillary buds, which are hidden by the united bases of the cotyledonary petioles, to be frequently alternate : petiole 1.2-1.8 in. long, flattened and channelled on inner side, bases of petioles united in a tube round the stem : lamina 0.4-0.5 in. by 0.5-0.6 in., thick, fleshy, 2-lobed, pink or reddish green. **Stem** erect, wiry, reddish in young stage, turning green and later greenish brown, very finely pubescent or glabrescent ; first internode (below first pair of foliage leaves) 2.8-5 in. long, slightly compressed, subsequent internodes much shorter, 0.5-1.5 in. long. **Leaves** simple, first pair opposite, subsequent leaves alternate. Stipules 0.1 in. long, caducous. Petiole 0.2-0.25 in. long. Lamina 2.3-3.5 in. by 1.2-2.3 in., ovate-oblong, acuminate, base rounded or cordate, entire, subcoriaceous, glabrous, dark green and shining above, slightly paler beneath, young leaves often reddish.

The first pair of opposite foliage leaves are very characteristic, and seedlings of the first year can usually be distinguished with certainty by their presence, though they may persist through part of the second season.

Stem development. The stems of sal seedlings are at first thin and whippy, but a stage is eventually reached when they become thickened, with a smooth cortex and an almost fleshy appearance. From this stage onwards growth is more rapid than it was previously, and the seedling may be considered to have established itself and to be ready to shoot upwards. Before long the smooth cortex begins to crack and rough bark to form, when the plant may be considered to have reached the sapling stage. The rate of development varies greatly according to local conditions. As an example of rapid growth in seedlings an instance may be quoted of a nursery plot at Mendabari in the Buxa district, Bengal, in which seed was sown in June 1911. In January 1915 the resulting seedlings, which were then 3½ years old and formed a dense clump, were thinned out : the forty-three plants which remained had a mean

girth and height of 5·5 in. and 14 ft., and a maximum girth and height of 8·4 in. and 16 ft. respectively. On several of the plants rough bark was already forming on the lower part of the stem. The plot in question is shown in Fig. 41, and subsequent measurements made in it are recorded below (p. 123). Such rapid growth, however, is possible only under specially favourable conditions, such as those which obtain in the Bengal Duars. In northern India healthy natural forest seedlings usually attain a height of about 4–7 in. and have two to four leaves by the end of the first season. Growth as a rule ceases about October, and the new season's growth begins about March–April. At Dehra Dun vigorous nursery-raised seedlings have attained maximum heights of 2½ and 4 ft. by the end of the second and third seasons respectively, the larger plants in the third season having developed thick stems. Mr. Hole¹ records the following measurements of vigorous artificially-grown seedlings at Dehra Dun :

56 seedlings 1 year old had a mean height of 13·6 in. and a maximum height of 23·5 in.

83 seedlings 2 years old had a mean height of 26 in. and a maximum height of 76 in.

Natural forest seedlings show development which is not only much slower but which, in the great majority of cases, is retarded owing to the habit of dying back described below.

Root development. Under normal conditions a healthy sal seedling quickly develops a long stout taproot, which may reach a length of 3 ft. by the end of the first season, though this is well above the average. Subsequent elongation and thickening of the taproot is also very marked. Under conditions unfavourable to the development of the root-system the taproot may show very feeble development or may be almost absent. A normal well-developed taproot usually has a fair number of comparatively short fibrous lateral roots on it, but the energy of the plant is concentrated mainly on the taproot, on the vigour of which the young plant has to depend for its ultimate survival. Under abnormal conditions large numbers of long lateral rootlets are produced, for example in water-cultures or where the roots run horizontally between layers of moist leaves without penetrating to the mineral soil. Mr. Hole² has shown that the development of the taproot is much poorer in seedlings grown under shade than in those grown in the open : this fact is of great importance where the establishment of reproduction is concerned.

Dying back. The dying back or complete dying off of sal seedlings in the forest is a phenomenon with which all who are acquainted with this tree are familiar. After a good seed-year, and with the timely commencement of the monsoon rains, the sal seed germinates readily, and thousands of seedlings are soon found covering the ground. The promise of abundant reproduction, however, is doomed to disappointment, for except under the most favourable conditions before a year is over the number of seedlings is greatly reduced by wholesale dying off, though a proportion may survive, the stem dying down and new shoots being sent up the following season. This dying back may consist of the death of the whole stem, a new shoot being produced from buds in the axils of the cotyledons, or of only a portion of the stem, growth

¹ Ind. For. Records, vol. v, pt. iv, p. 44.

² *loc. cit.*, pp. 56, 64.

being carried on by new shoots produced from axillary buds at different points on the stem. Dying back with subsequent recovery takes place when the taproot has developed with sufficient vigour to withstand the adverse influences which cause the death of the aerial portion of the plant.

Some years ago a large number of plots were laid out in many different parts of India, in places where natural sal seedlings had appeared in abundance after good seed-years. These plots were kept under observation for a series of years, and the results told a similar tale in each case. At the best the number of seedlings diminished steadily each year, while under less favourable conditions there was wholesale dying off, not a single plant surviving: where conditions were favourable a few seedlings in each plot ultimately established themselves, sometimes after dying back several times; but taking the plots as a whole the mortality was enormous.

The death or dying back of sal seedlings takes place at different times of the year, and, as will be seen later, may be due to various causes. In the rainy season mortality is very high. In dry localities the seedlings may survive the rains but die down in the ensuing dry season, suggesting drought as the cause. In frosty localities they are killed down by frost in the winter, and send up new shoots at the commencement of the following growing season. Although large numbers of seedlings ultimately succumb after a more or less lengthy struggle, during which they may die back several times, it is noteworthy that during the struggle a great development of the taproot takes place steadily, and that the struggle is essentially an underground one. Plants only a few inches high, which have died back repeatedly, if dug up will be found to have greatly thickened root-stocks which penetrate to a considerable depth. Those plants which at last succeed in establishing themselves cease to die back and begin to produce thick shoots: from this time onwards their upward growth takes place normally, and before long they begin to produce rough bark and may be said to have reached the sapling stage. The time taken in the process varies according to local conditions. In a favourable case recorded above the sapling stage was reached within $3\frac{1}{2}$ years. In the case of natural forest seedlings under conditions usually obtaining in north-western and peninsular India, the time occupied is very much longer, possibly at least ten years, and in many cases considerably more.

The dying back of seedlings under adverse conditions is not peculiar to the sal, but is seen in various other Indian species. In the case of the sal, although so prevalent it must be regarded as an abnormal process induced by external conditions and not as an inherent characteristic. In the Bengal Duars, where optimum conditions are approached, natural sal seedlings growing in the open do not ordinarily die back but shoot up with rapid growth straight from the seed. Seedlings raised artificially in nurseries in many localities, if carefully tended; do not die back but develop strong shoots at an early age. In the forests near Dehra Dun Mr. Hole's experiments, described below, have shown that favourable conditions can be produced under which seedlings do not die back, although wholesale dying back of natural seedlings takes place in the immediate vicinity. Even in northern India many natural forest seedlings do not die back, though their stem development may be retarded for years while the taproot is establishing itself.

The phenomenon of dying back, with subsequent establishment, gave rise at one time to a theory as to its cause which deserves some consideration. According to this theory the sal seedling is unable to establish itself and to start upward growth until its taproot has penetrated downwards to the permanent subsoil water-table: only then are supplies of water available sufficient to prevent further dying back and to enable upward growth to commence. This theory, if it is held to be of general application, is at once refuted by the fact that under favourable conditions sal seedlings do not die back, but may commence vigorous upward growth when their taproots are not many feet long in localities where the subsoil water-table is at a great depth, for instance in the *bhabar* tract of the Bengal Duars or, in the case of artificially-raised seedlings, in the neighbourhood of Dehra Dun. The fact is, as Mr. Hole has shown, that, other conditions being favourable, sal seedlings will survive and develop normally where the moisture in the soil does not fall below 3 per cent. in sand and 10 per cent. in loam.

The question of mortality among sal seedlings has been the subject of exhaustive study by Mr. R. S. Hole, the results of whose researches have been of the greatest value in determining the chief causes of death and in indicating the measures necessary to prevent mortality. His experiments, which were carried out at and in the neighbourhood of Dehra Dun, were commenced in 1909 and have extended over a series of years. They not only embraced pot-cultures, water-cultures, and work in the experimental garden, but also extended to the local sal forests, where highly interesting results were obtained in numerous control plots. The experiments have been described in some detail in the *Indian Forest Records*,¹ and it will not be possible here to do more than recapitulate briefly the principal results. They are as follows:

1. *Primary soil factors.* The primary factors which determine whether or not sal seedlings can thrive on a particular soil are (i) the water-content of the soil, and (ii) the aeration of the soil. Provided these are suitable sal seedlings will grow well on soils of widely different chemical and physical composition and will show little, if any, dying back.

2. *Primary causes of mortality.* Omitting cases of damage by frost, which are local, and injury by animals, insects, &c., two factors have been found to be of outstanding and primary importance in causing the death or dying back of sal seedlings: (i) an injurious soil factor which comes into operation in the rainy season, especially in the months of July and August; and (ii) drought, which causes widespread damage during the season of short rainfall from September to June. Of these two factors the former is the more important, since those plants which have developed vigorously during the rains are able to resist the subsequent damage from drought owing to their strong deep-going root-system, whereas weakly plants with a poorly developed root-system quickly succumb after the rainy season is over.

3. *Soil water-content.* Seedlings die or die back from drought when the water-content of the soil in contact with their roots falls to 3 per cent. and below in sand or sandy loam. Owing to the rapidity with which sand parts with its moisture, under similar conditions of environment and water-supply seedlings die or die back from drought most rapidly on sand, less

¹ Ind. For. Records, vol. v, pt. iv. Oecology of sal. I. Soil-composition, soil-moisture, soil-aeration (1914). II. Seedling reproduction in natural forests and its improvement (1916). III Soil-aeration and water-cultures (1916).

quickly on loam, and most slowly on leaf-mould. It is not necessary for the healthy development of sal seedlings that the roots should reach the permanently saturated layers of the water-table : a 3 ft. layer of forest loam is, in years of heavy rainfall, able to retain sufficient moisture for the healthy development of sal seedlings, even when separated from the subsoil by a waterless layer of stones.

4. *Injurious soil factor.* In years of heavy rainfall germination is better on sand than on water-retaining leaf-mould and loam. The death or dying back of seedlings during the rains is caused by an injurious soil factor due chiefly, if not entirely, to bad aeration. This injurious factor is operative mainly in non-porous soils in which the water-content is high and the water-free air space is small, and through which water does not percolate freely but remains for some time *in situ*. In such soils the mortality may be as high as 100 per cent. The injurious factor is aggravated by the presence of organic matter such as dead sal leaves : it is also aggravated by consolidation of the soil through mechanical pressure, the pore-space being thereby reduced. The injurious action is correlated with an accumulation of carbon dioxide in the soil-solution and a low oxygen-content, the latter indicating a condition adverse to free root-respiration. It is probable, though further proof is necessary, that the injurious action may be caused in part by the presence of one or more toxic substances in the soil which are directly poisonous to the roots. The toxic substance or substances are possibly in part secreted by the plant roots or by soil organisms, but they are probably produced mainly as a result of the decomposition of the organic matter in the soil : they can accumulate or become injurious only under conditions of bad aeration coupled with a high water-content, whereas they are rapidly dissipated and rendered innocuous by good aeration. That the injurious effects of bad aeration are not due to water as such, is proved by the fact that sal seedlings can be grown successfully in water-cultures. Bad soil-aeration retards root development and results in a superficial root-system : it is accompanied by a more or less extensive dying and rotting of the roots, which is worst towards the root apex.

5. *Effect of forest cover on other factors.* In the open with full overhead light but with light side shade and a light intensity of 0.3 to 0.7 (Clements's photometer) the percentage of seedlings which germinate and survive is decidedly higher, and the percentage which die back is decidedly lower, than in the shade of the forest with a light intensity of 0.05 to 0.08. The root development in particular is much better in the open than under shade (14.1 and 20.9 in. in two plots in the open, as against 4.7 and 7.3 in. in two plots in the shade). The inferior growth of sal seedlings in the shade of the forest is due primarily not to deficient light, to unsuitable air-temperature or air-humidity, or to a deficient supply of available plant food, but to an injurious soil factor. In the rains the inferior results in the shade are connected with the decomposition of humus, and are due to bad soil-aeration caused by a higher percentage of organic matter and water, a smaller water-free air space, and probably an accumulation of toxic decomposition products. In the dry season the high percentage of mortality in the shade is due to drought, and is the direct consequence of the poor root development during the rains. In May 1913 it was found that as a rule the moisture-content of the soil, both in the shade and in the open, approached the death limit in the surface layers, but increased on proceeding downwards ; it was also found that the moisture percentage below 9 in. in depth was higher in the open than under the shade of the forest close by. This emphasizes the advantage of a strong root development during the first growing season, that is the rainy season.

6. *Remedies for adverse conditions.* In order to ensure the survival of seedlings in the ensuing dry season, it is necessary to promote vigorous growth during the rainy season. The injurious soil factors can be readily eliminated and vigorous growth stimulated by aerating the soil, that is by digging it up,

and in loam by removing the dead leaves by sweeping or burning. Sowings on a fire-line have demonstrated that continued annual firing has no obvious injurious effect on the soil so far as its capacity to produce healthy seedlings is concerned. In sand, on the other hand, a mixture of dead leaves may be beneficial rather than otherwise, in assisting the retention of moisture. Vigorous growth of seedlings is further stimulated by the complete removal of the overhead canopy, side shade being retained in order to protect the seedlings from frost and to keep the soil moist during the dry season. In the Dehra Dun forests practically ideal development of sal seedlings can be secured by clear-felling in patches or strips not more than 100 ft. wide and preferably not more than 60 ft. wide, removing dead leaves, digging up the ground, artificially sowing sal seeds, and weeding during the first rains.

Mr. Hole's experiments have, it is true, been confined to one particular locality, namely, the Dehra Dun neighbourhood, where the normal rainfall is about 85 in. and the forests are of a fairly moist rather than of a dry type. In the very moist type of sal forest met with in the Bengal Duars seedlings will not survive on narrow cleared lines through the forest, owing to the excessive dampness of the soil and the adverse factors induced by it. Nevertheless, these experiments have covered a range wide enough to demonstrate the main causes of mortality in sal seedlings and to indicate the measures necessary to counteract the adverse factors: the details of these measures must naturally vary with local conditions. The further application of Mr. Hole's results can best be dealt with under 'natural reproduction' and 'silvicultural treatment'.

Other causes of injury. Among animals, pigs and porcupines, especially the latter, do a good deal of damage to sal seedlings in some localities, and rats also do much damage in grassy areas by gnawing through the taproot and the base of the stem. The seedlings are readily browsed by deer and cattle. They are subject to various forms of injury by insects, perhaps the most serious being the biting through of the taproot, probably by crickets. Sal seedlings are somewhat frost-tender, but have good power of recovery from the effects of frost. In localities subject to frost they are frequently killed back year after year; this occurs chiefly in grassy tracts. Protective measures are given below under 'natural reproduction' (pp. 97, 98).

SILVICULTURAL CHARACTERS. *Light.* Although the sal is able to persist under moderate shade, it is, strictly speaking, a light-demander and not a shade-bearer, its best development being secured by the admission of complete overhead light from the earliest stage, though as already stated young plants require side protection from frost and drought where these are factors to be considered. In dense pole crops numerous small whippy shoots are often found in abundance; these might be mistaken for seedlings, but on examination they are often found to spring from the bases of saplings which have been killed in the struggle for existence. As long as the cover remains unbroken these shoots continue in their whippy form until they eventually die, but if the cover is broken one or more thick shoots are sent up from each stool, and these eventually establish themselves.

Root-system. Normally the sal produces a long stout taproot of great length, which reaches down to strata moist enough to supply the water requirements of the tree, and in the plains can, as a rule, be traced down to the



FIG. 41. *Shorea robusta*, vigorous clump of seedling plants $3\frac{1}{2}$ years old, just thinned out, Mendabari, Buxa, Bengal : mean girth 5.5 in., mean height 14 ft., maximum girth 8.4 in., maximum height 16 ft.



FIG. 42. *Shorea robusta* coppice-with-standards coupe in which the coppice has failed owing to the felled trees having suffered from drought two years previously, Gorakhpur, United Provinces.

permanent subsoil water-level. In addition stout lateral roots are produced at no great depth below the surface, while deeper down are found numerous fibrous lateral nutrition rootlets ramifying in all directions where there is sufficient moisture. In an investigation in 1913 into the nature of the subsoil in sample plots, interesting observations were made during the digging of six wells in forest on old alluvium in the Gorakhpur district. It was found that stout lateral roots were produced at a depth of 1 to 8 ft., the actual depth varying in different places; the soil in which these roots were found varied, but as a rule the roots were nearer the surface in clayey than in sandy soils. Below these roots, at a depth varying from 8 to 14 ft., and in some cases extending down to water-level, were numerous fibrous lateral rootlets, always in moist strata, the soil varying from pure sand to pure stiff clay. The depth of the water-level varied from 12 ft. 9 in. to 18 ft. 6 in. In one case the soil throughout was a very stiff clay, and the trees were gnarled and stunted. Here the fibrous rootlets were at a depth of 11 to 14 ft.; they were unable to pierce the stiff clay, but every fracture in the clay revealed masses of minute rootlets flattened out in the fissures. Below 14 ft. the clay was too moist and pliant to allow of fissures, and sal rootlets were absent. It is not unlikely that the fact that in stiff clay the rootlets are confined to the fissures may be due as much to the need of air as to the inability of the roots to pierce the clay. In a sandy subsoil the rootlets were found to ramify at will where the moisture was sufficient.

In some localities the taproot in stiff clay soil has been observed to have disappeared, probably owing to decay, and the trees, which are stunted and gnarled, are supported by the more or less superficial lateral roots; such trees are easily blown down by wind.

So far as has been observed the sal does not produce root-suckers. Shoots are sometimes produced low down on stools, some little distance below ground-level, and curving outwards appear above ground some inches away from the stool, but these can hardly be called root-suckers.

Coppicing power. As a rule the sal coppices well up to a moderate size. Shoots are rarely produced from the top of the stool, but usually from the side of it near ground-level. Mr. McIntire¹ says that in the dampest parts of Bengal, that is in the *tarai* and the Tista valley, sal is a bad coppicer. In coppice experiments near Dehra Dun in 1908-9, the best shoots were produced by stools not exceeding 2 ft. in girth. In Gorakhpur nearly all the trees up to 3 ft. in girth are found to coppice well. A number of measurements made by me in that district in 1911 showed that the strongest shoots were produced by stools varying from 10 in. to 4 ft. 2 in. in girth; within these limits the vigour rather than the size of the stools appeared to determine the vigour of the shoots produced. In Bahraich experiments carried out in 1909 resulted in no shoots being produced by stools over 4 ft. 10 in. in girth. Mr. Leete² found that in the Charda forest of Bahraich shoots were produced in abundance only by stools under 3½ ft. in girth. Mr. Haines says that in Bengal coppice-shoots are almost universal from stools under 1 ft. in girth, not common from stools over 2 ft. in girth, and only occasional from stools 2 to 3 ft. in girth.

¹ Notes on Sal in Bengal, For. Pamph. No. 5, 1909.

² Ind. Forester, xxv (1899), p. 326.

On rare occasions stumps of large size are found to produce coppice-shoots : in 1916 in the Singhbhum forests I found a hollow stump 9 ft. in girth, cut 3 ft. high, producing a shoot from near the top.

The number of shoots produced per stool varies greatly. Measurements made by me in the Tikri forest, Gonda, in 1911, in three plots of 4 acres each in coupes one and two years old gave the following results :

1. Age 1 year, average 2.2 shoots per stool.
2. Age 2 years, ,, 1.7 ,, ,,
3. Age 2 years, ,, 1.8 ,, ,,

Measurements made the same year in Pilibhit in a coupe one year old showed an average of 4 and a maximum of 10 shoots per stool. As many as 20 shoots have been observed on a single stool : in such cases, however, superfluous shoots are killed out, and as a rule only about 1 to 3 shoots survive to an age of say twenty or thirty years.

Trees whose vitality has been seriously impaired by drought or otherwise coppice indifferently or not at all, though experiments carried out in Bahraich in 1902-3 showed that trees dead for some distance from the top in many cases coppiced well. For a few years subsequent to the abnormal drought of 1907 and 1908, in the forests of Oudh coppice reproduction failed entirely in certain coupes where the trees had been badly affected, nothing but a sea of grass resulting from the fellings (Fig. 42). Apart from drought, coppice has failed signally in some parts of the Gorakhpur forests. This is probably due, in part at least, to the unsoundness of many of the trees felled, this being no doubt attributable to past burning and maltreatment, which has resulted in stumps which are hollow or lacking in vigour. Experiments in the Central Provinces have shown that the season of cutting has a marked influence on the production of coppice-shoots : cutting should be completed before the growing season begins, that is, before the hot season, for if it is carried out in the hot season weak shoots result in a large number of cases.

Under certain conditions the height at which stools are cut has an influence on the resulting shoots. It was noticed in Oudh some years ago that in dry localities and dry seasons stools cut a few inches from ground-level produced better results than those cut flush with the ground. This was due to the fact that the stools died down for a few inches from the top in the hot season, the cortex separating from the wood : in the case of stools cut high, although the upper part of the stool dried up the lower part remained alive and produced shoots, whereas in the case of stools cut flush with the ground the part at ground-level and immediately below it dried up, reducing the surface capable of producing shoots. Experiments carried out in 1910-11 in the Siwaliks confirmed this.

Mr. A. E. Osmaston ¹ has described experiments in high and low coppicing carried out in the Gorakhpur district. Three forms of coppicing were tried : (a) cutting flush with the ground and trimming in the form of a convex cone, (b) cutting 4 to 6 in. high with similar trimming, and (c) cutting 4 to 6 in. high without trimming. The following results were obtained : (1) as regards

¹ Ind. Forester, xxxvii (1911), p. 424.

the proportion of stumps producing shoots, (a) showed results inferior to (b) or (c); (2) as regards the average height of shoots produced there was a slight but well-marked increase in height in the case of (b) relative to (a) and of (c) relative to (b); (3) as regards the number of shoots per stool, the method of coppicing had little if any effect.

Experiments were carried out in Bahraich, in which two one-acre plots side by side were coppiced in March 1909; in one of these the stools were cut flush with the ground and in the other they were cut a few inches high. In the former 86 per cent. and in the latter 95 per cent. of the stools sent up shoots.

Drought. The most severe drought which has occurred in sal tracts within the memory of man is that of 1907 and 1908, which caused extensive damage in the *tarai* and plains forests of Oudh, and considerable local damage in the *tarai* forests farther west; the forests of the outer hills were only slightly affected.

In 1913 I published the results of an investigation into the effects of this abnormal drought and the causes of the damage done by it.¹ The effect was found to vary from place to place: in some cases the trees died off wholesale over patches of considerable extent (Fig. 43), while in many cases they died off in small groups. In coppice-with-standards coupes the standards were often found to be badly affected, while the coppice escaped (Fig. 45). All the facts of the case pointed to the direct cause of the damage being due to the failure of the monsoon rains of 1907 and 1908, resulting in the lowering of the subsoil water-level and the desiccation of the soil above that level; measurements in different wells throughout the Oudh forests showed a fall in the water-level varying from 2 to 26 ft. It was noticeable that deep-rooted species suffered more than shallow-rooted species, sal suffering more than any of its companions. The reason of this appears to be that with the lowering of the water-level the strata for some distance above it, from which the roots of the deep-rooted species drew their supplies of water, became too dry to afford the requisite supply of moisture; on the other hand the surface feeders obtained sufficient moisture from the scanty rainfall which fell in the years of drought and moistened the surface layers.

Cases of wholesale dying off of trees over large patches were found, by means of a series of well-borings made across these areas and adjacent unaffected areas, to be due to the presence of thick deposits of pure sand for some distance above the normal water-level. When the water-level sank these deposits of sand were unable to retain a sufficiency of water to keep the trees alive; in the adjoining unaffected areas, on the other hand, the subsoil contained no thick layers of sand, but consisted of varying proportions of sand and clay constituting a subsoil more retentive of moisture. The thick deposits of pure sand in these alluvial tracts may be taken to represent former sand-banks produced by river action, and now buried several feet below the surface owing to the superimposition of more clayey beds; this would explain the fact that in many cases the badly-affected areas, denoting the presence of these sand-banks, were long and narrow in shape and were observed to follow regular lines of varying breadth.

¹ For. Bull. No. 22.

A study of the causes of the damage done by and the effects of the abnormal drought in question, which in some localities led to the entire suspension of working plans operations, with the object of removing dead trees, indicated the hopelessness of devising measures for counteracting its effects to any great extent. The following measures may serve to mitigate the extent of damage caused by a similar catastrophe in future :

1. High forest would appear to be more suitable than coppice-with-standards in localities subject to drought, in view of the susceptibility of standards to injury.

2. The retention of a suitable mixture of drought-hardy trees in sal forests is desirable. Among those found to be particularly hardy during the abnormal drought in the Oudh forests were *Ficus* spp., *Diospyros tomentosa*, *Stereospermum suaveolens*, and *Miliusa velutina* ; slightly less hardy, but still decidedly hardy, were *Gardenia turgida*, *Holarrhena antidysenterica*, *Ougeinia dalbergioides*, *Cassia Fistula*, *Cordia Myxa*, *Bauhinia racemosa*, *Casearia tomentosa*, *Butea frondosa*, *Bridelia retusa*, *Odina Wodier*, *Eugenia Jambolana*, *Ehretia laevis*, *Mallotus philippinensis*, *Carissa spinarum*, *Lagerstroemia parviflora*, *Careya arborea*, *Grewia* spp., *Kydia calycina*, *Randia uliginosa*, *R. dumentorum*, *Zizyphus Xylopyrus*, and *Aegle Marmelos*.

3. An undergrowth of drought-hardy species is of special importance : even though the presence of a heavy undergrowth was not proved to be a preventive of damage by drought, the value of an undergrowth of hardy species as a soil-covering, in the event of the destruction of the overwood by drought, would be considerable.

Frost. Sal withstands frost better than many of its associates, but from the fact that it often occurs in grassy tracts and other localities subject to severe frost, it is particularly exposed to injury, and suffers accordingly. The commonest forms of injury are the killing back of seedlings and coppice-shoots, often for many years in succession, until they are at last able to shoot up, and injury to the crowns of poles and saplings, the leading shoots being killed and numerous epicormic branches being produced up the stems. Trees affected in this way have a characteristic appearance not unlike that of a Lombardy poplar (Fig. 46).

The abnormal frost in the early part of 1905 did enormous damage in the sal forests of northern India, particularly on low-lying ground. Saplings and small poles were killed down to ground-level, while large poles and even trees of considerable height had their tops killed for 10 to 20 ft. or more. Observations made some years later in the Dehra Dun forests showed that the loss of increment alone amounted on an average to at least ten years' growth. More serious, however, was the fact that rot had in most cases spread down the interior of the stem, starting from the base of the dead top. One or more new leaders had been produced from the living tissue at this point, the result being a bayonet-shaped or forked stem. For years after the occurrence of the abnormal frost the new leaders so produced frequently broke off, owing to wind, at the tender callus at their base. Trees damaged in the manner described can never be expected to produce clean sound boles, and one lesson learned from this abnormal frost is that it would be more profitable to cut back as many badly damaged poles and saplings, as circumstances will permit, for



FIG. 43. *Shorea robusta* forest killed by severe drought of 1907 and 1908, South Kheri, United Provinces.



FIG. 44. *Shorea robusta* root-stock produced on *chandar* land, Pilibhit, United Provinces : hollow decaying taproot cut through (bottom of picture), several lateral branches, and several groups of shoots from gnarled remnants of stump.



FIG. 45. *Shorea robusta* standards killed in coppice-with-standards by the abnormal drought of 1907 and 1908, Gonda, United Provinces.

a few years after the occurrence of such a frost, thus allowing of new healthy coppice growth taking their place.

In the Dehra Dun forests it was noticeable during the abnormal frost of 1905 that overhead shade which was sufficient to suppress young sal growth was not sufficient to prevent damage to it by frost. A similar observation has been recorded by Mr. C. M. McCrie¹ in the case of an abnormal frost in February 1916 in the Balaghat district, Central Provinces; in a *Pinus longifolia* plantation near Supkhar sal shoots which were so thoroughly shaded by the pine as to be on the verge of suppression had been more or less cut back to ground-level by frost. These observations are of great importance in showing that in a really severe frost overhead cover cannot be relied on to afford protection. On the other hand the value of side protection has been demonstrated in the experiments referred to above under 'the seedling'.

The value of air circulation as a preventive of frost damage is often seen in grassy tracts, where sal establishes itself more readily along the edges of cleared lines, and in similar places where there is free air circulation, than in the grass-covered portions of the area. The value of side protection in such areas is also seen from the fact that sal tends to establish itself preferably beside clumps of trees or along the edge of the forest. Frost damage becomes accentuated in dry years, and hence in years of abnormal drought frost damage may occur in localities ordinarily free from it.

One of the most remarkable effects of frost is seen in the grassy blanks in the Pilibhit and South Kheri forests of the United Provinces, and known locally as *chandar* lands. These blanks are thickly covered with a shrubby growth of sal, the shoots springing up annually from a thickened root-stock and being killed back every year by frost (see Figs. 21 and 22). These *chandar* lands vary in extent from a few acres to some hundreds of acres. They are situated on the alluvial plains, some of them occupying slight depressions, while others are not appreciably lower than the surrounding forests. The soil is often, but not invariably, pure micaceous sand. Some of the *chandar* lands are fire-protected and some are burnt annually. As far as appearances go fire-protection seems to have no appreciable effect on the establishment of sal reproduction; it results in a very rank growth of grass, chiefly *Anthistiria gigantea*, but does not appear to assist the sal in any marked degree. In mild seasons some of the sal shoots escape damage by frost here and there, singly or in groups, and after a succession of mild seasons may even establish themselves permanently. The most favourable positions for the establishment of the sal are along the edges of roads and fire-lines, where owing to the free air circulation established saplings often form a regular fringe, or along the edges of the forest and in the immediate neighbourhood of clumps of trees, where side protection is obtained. The sal shoots which spring up annually on *chandar* lands are found in clumps like coppice-shoots; they are comparatively thin, and as a rule reach a height of 3 or 4 ft. They spring from an enlarged woody root-stock, there being one or more clumps to each root-stock, according to the size and vitality of the latter. In comparatively young root-stocks only one clump of shoots is sometimes seen, and a regular taproot is found; the latter, however, generally rots away as the stump increases in age, and is

¹ Annual Forest Report, 1915-16.

replaced by long lateral roots spreading not far below the surface of the ground. In many cases the original stool has entirely decayed, leaving a straggling gnarled or twisted growth, which tends to branch in different directions, each branch sending out a clump of shoots (see Fig. 44). In such a case the clumps of shoots often appear to form a ring which gradually enlarges until it is several feet in diameter; this ring represents the original outer growing portions of the stump which have spread centrifugally with advancing age. Sometimes portions of this ring detach themselves from the original stump owing to the decay of the latter, and form independent root-stocks.

The origin of *chandar* lands is not known with certainty. It has been suggested that they represent former swamps, but this seems unlikely owing to the fact that the soil is often pure sand, that they do not necessarily occupy depressions, and that sal does not grow in swamps and never could have originated in them. It is possible that they may be areas formerly cleared of tree-growth by man. In this case the stumps were probably subjected to ill treatment, by burning or otherwise, sufficiently severe to impair their vitality: this conjecture follows from the fact that trees recently felled, and not fire-protected, have been seen to reproduce themselves at once by vigorous coppice-shoots in areas adjoining or situated within existing *chandar* lands, the annual frosts being insufficient to kill back the coppice-shoots which sprang from the felled trees. Another possible theory is that the vitality of the stools may have become impaired by some abnormal climatic phenomenon such as excessive drought; an examination of the subsoil of *chandar* lands as compared with adjoining forest land might throw some light on the subject.

Attempts have been made to restock *chandar* lands, but so far experiments carried out with the view of effecting the establishment of existing sal shoots have not proved successful. These experiments have consisted of sheltering sal with grass cowls, clearing narrow strips to produce air circulation, producing a pall of smoke and water vapour, excavating parallel drains, and introducing frost-hardy nurses. It is probable that the difficulty will eventually be solved by restocking *chandar* lands with frost-hardy species when the most suitable species and the best methods of cultivating and protecting them have been ascertained: so far damage by pigs and porcupines has been the most serious danger to be contended with in this respect. If irrigation could be introduced, this might help matters by producing more moisture in the air and thus lessening the damage from frost.

Fire. Sal is one of the most fire-resistant of all the species of its region: this is clear from the manner in which it establishes itself in burnt savannahs where the majority of species are unable to survive. The process of establishment is no doubt slow, since the sal is burnt back year after year, but its power of recovery from the base is remarkable. Former damage from fire is undoubtedly the cause of much unsoundness and hollowness in sal trees at the present day, particularly in forests of the drier types. The sal trees in the Bengal Duars, however, have been observed to be remarkably sound, even at the base, and this in spite of the fact that the majority, if not all of them, must have originated in burnt savannah lands. In the dry and semi-moist types of sal forest the advantages of fire-protection are everywhere most marked; this is particularly the case for some years after fire-protection has

been introduced in forests hitherto subjected to burning, and young growth previously burnt back annually is able to start upward growth. In the moist types of sal forest occurring in Bengal and Assam the effects of continued fire-protection on the natural reproduction of the sal, in causing the growth of a dense evergreen undergrowth and in introducing unfavourable soil factors, are most adverse, as has been explained above.

Damage by fire is much aggravated after the occurrence of severe drought, such as that which affected the forests of Oudh in 1907 and 1908. The trees which are killed or partly killed by drought, and have strips of dead bark clinging to them, may be wholly consumed by fire, which runs up the dead bark and causes crown fires of great intensity. Moreover, the lightening of the canopy owing to the death of a certain proportion of the trees induces a rank growth of grass which still further aggravates the risk of fire and the damage caused by it.

Storms. Owing to its strong deep root-system the sal is not ordinarily liable to be thrown by wind, but on badly-drained clayey ground the taproot sometimes rots, and the trees are readily blown down. By far the greatest damage by storms and hail is occasioned by the destruction of the flowers and immature fruits from February or March to June. Hailstorms occasionally do damage by stripping off the young leaves and twigs.

Animal damage. Injury by animals occurs in the younger stages. Seedlings, as already mentioned, suffer much from damage by pigs and porcupines, which uproot the young plants. Wild elephants sometimes strip the bark off the lower parts of poles and smaller-sized trees. Browsing by deer and cattle is responsible for a great deal of damage, particularly in coppice coupes. Heavy grazing may be responsible for a complete absence of natural reproduction, partly owing to browsing and partly owing to the hardening of the soil. As the sal plants put out their fresh foliage early in the hot season when the grass is dry and unpalatable, they are particularly susceptible to the attacks of browsing animals: this is more especially the case in fire-protected tracts, where fresh green grass does not spring up early in the hot season, as it does in burnt areas. The sal has numerous insect enemies, but it is beyond the scope of this work to describe them. The barking of logs as soon after felling as possible is recognized as a necessary precaution to prevent the ingress of wood-boring beetles which lay their eggs in the bark of fallen trees.

Parasitic plants. In some localities, for instance in parts of Bihar and Orissa, sal suffers much from the attacks of *Loranthus*; in such cases affected trees should be cut out as far as possible in thinnings.

A virulent fungoid pest of the sal has recently come to light in the shape of *Polyporus Shoreae*, Wakefield, the sal root fungus.¹ This fungus was first detected in 1914 by Mr. C. F. Beeson in the Bengal Duars, where it must be held accountable for numerous mysterious cases of death among sal trees in that tract which had been noticed for several years previously. It has since been reported to a greater or less extent in other parts of Bengal and in parts of Assam, Bihar and Orissa, the United Provinces, and the Central Provinces. It appears to be commoner in moist than in dry types of forest. The outward sign of the fungus attack is the death of sal trees, usually two or three together

¹ Kew Bull., No. 3, 1916, p. 72.

or in larger groups. At the base of an affected stem may be found groups of dark brown bracket-like sporophores, often 15 in. or more in diameter; these are soon consumed by white ants, so that in many cases they are not traceable. If the roots of the tree be cut open they will be found to be permeated by the whitish mycelium, which usually appears in the form of numerous flecks or pockets. The mycelium attacks roots of all sizes, sometimes completely destroying the taproot, and spreads into the base of the bole. The freshly attacked tissues of the cortex have a characteristic odour of decaying resin, and are wet and sticky. This fungus is at present under study with the view of devising methods of combating its ravages.

Mr. Haines¹ records from Orissa another fungus, not yet identified, which he terms the sal thicket fungus. 'This form, or species,' he says, 'is not apparently a root fungus, but the mycelium appears on the young stems and branches and spreads on to the leaves. In older parts it assumes the form of thicker white strands and bands. It often appears to originate near a wound caused by the breaking of a branch, the leaves turn brown and die, branches die off and break away at the stem or the whole top dies and breaks off. Ultimately, after many attempts at putting out new shoots, which causes a characteristic nodose appearance of the stem, the whole plant may die. This dying back and breaking off of the branches may be the cause of the fungus appearing to originate at wounds. Now, the great point about this fungus . . . is that it always appears in overcrowded thickets, or on saplings under the shade of bamboos, or in other places where light is apparently insufficient; and it may, therefore, I think, be rightly classified among those bad conditions producing unsoundness which can be removed by future treatment. Improvement fellings, thinnings, and cleanings seem to be the remedy, and in grave cases, almost certainly, fire and coppice.'

Mr. Haines has also found on sal trees in the Palamau district, Bihar and Orissa, a fungus closely resembling *Xylaria polymorpha*, which is parasitic on the oak in Europe; it was found on a number of dead sal trees and on a half-green tree.

NATURAL REPRODUCTION. The natural reproduction of the sal presents many features which have always been a puzzle even to those who have studied the question for years. In some localities reproduction springs up in such profusion and with such vigour that nothing can stop it; in others, where, as far as the eye can judge, conditions appear to be similar, reproduction is completely absent for no apparent reason. The problem of the natural reproduction of sal, as of other species, can best be approached by considering separately the various factors affecting it. If these are understood it may be possible in individual cases to assign reasons for good or bad reproduction and to suggest remedies for the latter. Some examples will also be quoted with the view of illustrating certain points of interest connected with the subject: some of the examples show that a combination of circumstances specially favourable to natural reproduction is in some localities of rather rare occurrence. The various factors which bear on natural reproduction may be conveniently considered under three heads: (1) seeding, (2) germination, (3) establishment of the seedling.

¹ Ind. Forester, xliii (1917), p. 311.

1. *Seeding.* Information on seed-bearers and seeding has been given under 'flowering and fruiting'. A seed-crop of good promise may be wholly or partially destroyed by storms or hail between the time of flowering and the time of ripening of the fruit. A report from the Santal Parganas states that 80 per cent. of the fruit-crop is blown down in the hot season before the fruit ripens, and that of the remaining 20 per cent. only a very small proportion germinates.¹ In this case the lack of reproduction may be put down mainly to unfavourable seeding conditions. The seed-crop is sometimes much damaged by insects, while in some localities considerable quantities of seed are destroyed by porcupines after falling. As regards the distance to which seed is ordinarily carried by breezes at the time of ripening, in 1910, following on a very favourable seed-year, seedlings were noticed in grassy blanks in the Dehra Dun forests well over 100 yds. from the nearest seed-bearer. This distance perhaps represents the limit to which seedlings spring up in any abundance on blank areas under ordinary conditions, though fruits are no doubt carried very much farther by high winds.

2. *Germination.* The most important factor affecting the germination of the seed is the occurrence of the monsoon rains. The seed falls at or immediately before the commencement of the rains, and if they are delayed many days after the fall of the seed, germination fails. In this way an abundant seed-year may fail partially or entirely to effect any natural reproduction: the combination of a good seed-year and timely commencement of the monsoon, resulting in abundant reproduction, is not of such common occurrence as might be supposed.

Experiments at Dehra Dun have shown that even with favourable rainfall conditions a certain proportion of the seed perishes during germination on bare hard ground exposed all day to the sun, through the radicle being dried up before it can penetrate the soil; where there is protection by grass there is less mortality from this cause. In very damp places, again, the radicle sometimes rots during germination, death resulting. The radicle is also subject to insect attacks. The effect of a thick layer of dead sal leaves on the germination of the seed is most marked; an experiment which I carried out at Dehra Dun in 1914 gave the following results: ²

In the open, exposed to the sun, sal seed falling on a layer of dead leaves fails to germinate, or if it does germinate it perishes rapidly: under shade, with complete protection from the sun, the seed germinates satisfactorily. In the latter case, however, as will be seen below, the seedlings fail to survive after the end of the rainy season. Side by side with the leaf-covered plots were bare plots with the soil completely exposed, on which sal seed was also scattered. On these bare plots germination was quite satisfactory both in the shade and in the open. Applying these results to forest conditions, although there will usually be patches of bare ground varying in extent on which germination is successful, on the other hand there will generally be patches, either under shade or in gaps exposed to the sun, where the dead leaves have accumulated sufficiently to cause a certain proportion of failure. The most practical remedy would be the burning of the layer of leaves when a good seed-year is in prospect.

¹ Ind. Forester, xxvi (1900), p. 389.

² *Ibid.*, xlii (1916), p. 57.

Observations made in the Dehra Dun forests in 1910, a very favourable seed-year, showed that germination takes place successfully under the densest forest shade. Mr. Hole¹ has, however, demonstrated that in these forests the percentage of germination in the shade of the forest is lower than it is in the open with full overhead light, but with light side shade.

The aptitude of sal seed for germinating on very porous soil is sometimes exemplified in exaggerated form, as in a case noticed in December 1910 at the side of a road running through sal forest near Dehra Dun, where numbers of vigorous sal seedlings were found growing on a heap of road-metal about 1 ft. high; they had sent their taproots down through the loose metal into the earth beneath and had firmly established them there.

3. *Establishment of the seedling.* (a) *Dying back.* The main factors affecting the establishment of natural reproduction are those concerned with the death or dying back of seedlings. These have already been dealt with in detailing the results of Mr. Hole's experiments, under 'the seedling'. To recapitulate briefly, these experiments showed that the chief causes of mortality are: first, an injurious soil factor which is operative during the rainy season, and which may be termed bad soil-aeration; and second, drought, which acts during the season of short rainfall from September to June. The former is present chiefly in non-porous soils with a small water-free air space and a high percentage of water and organic matter. The latter is the direct consequence of the former, since in a badly-aerated soil the root-system is insufficiently developed to be able to withstand the effects of the dry season. As regards measures necessary for securing reproduction, Mr. Hole classifies sal forests into moist and dry types, in which bad soil-aeration and drought respectively are the dominant factors, and advocates the following treatment in either case. In moist forests: clear-felling in strips or patches, removal of dead leaves (if necessary by burning), working up the soil, sowing sal seed, and weeding during the first rains; this secures ideal conditions for the development of sal seedlings, these conditions being a well-aerated seed-bed free from raw humus, full overhead light, and light protective side shade. Where these measures are impracticable the alternative proposed is to remove dead leaves by light leaf fires or otherwise, thereby increasing the proportion of seedlings, and then to remove the overhead cover early. In dry forests two methods are suggested: (i) introducing an underwood as a soil-protection, thus in time converting the forest into one of the moist type, which could then be treated as such; (ii) preventing the run-off of rain-water and encouraging its percolation into the soil by surface cultivation, trenching, or small embankments, this being accompanied if necessary by mulching in the dry season.

(b) *Effect of dead leaves.* An experiment dealing with the mechanical effect of a layer of dead leaves on the germination of the sal seed has already been alluded to; the effect of such a leaf layer on the survival of the resulting seedlings has been brought out by the same experiment. It was found that seedlings which germinated on a layer of dead leaves under shade developed satisfactorily above ground during the first rains, but the taproots, instead of descending into the mineral soil, spread laterally between the layers of wet leaves, deriving sustenance from the moist earthy matter there, and sending

¹ Ind. Forester, xlii (1916), p. 59.



FIG. 46. *Shorea robusta*, effect of damage by frost, Lansdowne division, United Provinces.



FIG. 47. *Shorea robusta* moist forest opened out and burnt with the view of inducing a growth of grass and a dense growth of *Macaranga* and *Albizia*.

out long fine lateral rootlets. There was no sign of rotting of the roots as in badly-aerated soil, but the roots had no foothold, and the seedlings could easily be pulled up with all the roots intact. In consequence nearly all the seedlings died off when the layer of leaves dried up after the end of the rainy season, many falling over for want of support; some survived for a few months where the leaf layer was scanty, but these eventually succumbed. In the case of seed sown on bare ground in adjacent plots, both under shade and in the open, the seedlings produced long taproots which obtained a firm hold in the mineral soil. It is thus evident that the removal of the layer of dead leaves on the ground, by fire or otherwise, is an aid to reproduction in counteracting the mechanical effect alone of the leaf layer.

(c) *Light*. The effect of light, as such, on the establishment of natural reproduction requires further investigation. It is a matter of common observation everywhere that the admission of full overhead light is necessary for the best development of a young sal crop. Mr. Hole's experiments have shown that in the open with full overhead light, but with light side shade, the percentage of seedlings which germinate and survive is decidedly higher, and the percentage which die back is decidedly lower, than in the shade of the forest; he ascertained, however, that the inferior results in the forest shade were due primarily to an injurious soil factor connected with the decomposition of humus and not to deficient light. Thus in the case of young seedlings, although want of light in itself may possibly not become an adverse factor until a certain degree of shade is reached, its correlation with factors which are adverse even under slight overhead shade is of importance. The protective value of side shade, as opposed to overhead shade, has already been referred to.

As a general rule, other conditions being favourable, the admission of light sufficient to cause the appearance of grass in moderate quantity will induce the appearance of sal reproduction, the establishment of which depends on a drastic opening out of the canopy. An exception, however, should be noted in the case of the very moist types of forest occurring in the Duars of Bengal and Assam and in certain other localities. Here the admission of light results in a rank growth of weeds and climbers which effectually prevents the establishment of sal reproduction, even in places where the undergrowth is cut and burnt to induce a growth of grass (see Figs. 47 and 48).

(d) *Frost*, as a factor adverse to natural reproduction, is of importance in open places, chiefly in grassy savannahs and blanks within the forest where seedlings may be killed back year after year. Under the cover of a canopy frost does not as a rule affect young plants except in abnormal years, as in the spring of 1905, when extensive damage was done even under fairly dense overhead cover. In grassy savannahs seedlings often remain undamaged as long as they are sheltered by the grass, but as soon as they appear above the level of the grass they are cut back by frost year after year. In such places reproduction establishes itself best along the edge of the forest, where it obtains side protection, or under and around isolated trees or clumps of trees; one of the most important protective trees in the savannah tracts of northern India is *Eugenia operculata*. Along the sides of roads or cleared lines running through frosty savannahs natural reproduction tends to establish itself

more readily than on the grass-covered ground owing to the freer circulation of air.

The value of side shade as a protection against frost and drought is well recognized in European forestry, and Wagner¹ has shown that in the case of the spruce lateral protection from the south-east gives the greatest immunity from damage by these agencies. The value of side protection has been similarly corroborated by Mr. Hole in the course of experiments alluded to above. He found that in localities subject to frost in the Dehra Dun forests, whereas light side shade on the south is not sufficient to protect sal seedlings from frost on the edge of an open grass-land surrounded by forest, seedlings springing up on a continuous cleared strip 100 ft. wide running ENE. to WSW. suffered no damage. He also found that in an area subject to severe frost the plan of clear-felling a gap 60 ft. wide, hoeing up the ground, sowing sal seed, and weeding during the first rains not only secured practically ideal development but prevented any frost damage.

(e) *Grazing.* Damage done by browsing is worst in the hot season when the fresh young sal leaves appear, as they are preferred to the dry withered grass. In burnt grassy areas the new green grass which springs up is preferred to the sal shoots, and the latter are less exposed to damage by grazing. Where heavy grazing is admitted the natural reproduction of sal may be entirely prevented, while the exclusion of grazing may result in plentiful reproduction where none existed before. Absence of reproduction in grazed areas may be due as much to the hardening of the soil by the tread of the cattle as to actual browsing. This hardening of the soil is particularly noticeable round the edges of the forests, where cattle are apt to congregate to escape the heat of the sun outside, or, in plains forests, on slightly rising ground, where they collect during the rainy season to escape the floods.

(f) *Hardened soil and bad drainage.* Natural reproduction frequently fails to establish itself on soil which has become hardened by grazing or otherwise, or is stiff through an excess of clay, or where the drainage is bad. Such conditions are common in some of the plains forests, as in parts of the Gorakhpur district, United Provinces. Here experiments have shown that a heavy opening of the canopy, thorough digging of the soil, and the exclusion of grazing are sufficient to ensure good reproduction on the worst and stiffest soils. In the Kalianpur block of the Haldwani forest division, United Provinces, in an area which had been heavily grazed for years and in which the soil had become excessively hard and barren, a plot was fenced off in May 1913, and within it the soil was dug up. In November the whole plot was found to be covered with seedlings, while the surrounding ground was quite bare. These examples serve to indicate the quick response to thorough aeration of the soil under the most unfavourable conditions.

(g) *Fire and fire-protection.* Observations everywhere show that in the dry and moderately moist types of forest found throughout the greater part of the north-western and peninsular sal regions the results of fire-protection on the establishment of natural reproduction are wholly beneficial, and that fire is one of the most serious obstacles to its successful establishment. Prior to the fall of the seed, however, fire is useful in removing the layer of dead

¹ C. Wagner, Die Grundlagen der räumlichen Ordnung im Walde.



FIG. 48. *Shorea robusta*, experimental seedling felling in moist forest, the overwood being opened out and undergrowth cut and burnt, resulting not in sal reproduction but in a dense mass of weeds and climbers, Goalpara, Assam.



FIG. 49. *Shorea robusta*, dense mass of natural reproduction up to 2 ft. high under *Macaranga denticulata* on an abandoned fire-line, South Muraghat forest, Jalpaiguri, Bengal.

leaves and thus increasing the number of seedlings which germinate and survive. In grassy tracts, also, where continued fire-protection in the case of certain species of grass produces a dense matted growth, fire before the fall of the seed is beneficial in enabling it to reach the ground and to find a good germinating bed.

In the very moist sal forests found in the Bengal Duars and in Assam, however, continued fire-protection has so altered the type of forest that natural reproduction cannot now establish itself. The Duars forests have been described above (pp. 70-73). It has been explained that these forests originally sprung up in burnt savannah lands, the process being still in operation where fire-protection has not yet been introduced. The process of establishment of reproduction is doubtless a slow one, as the fires in these grassy tracts are of great severity, but the sal after repeated burning back eventually establishes itself; the process is illustrated in Figs. 31, 32, and 33. The introduction of fire-protection must for a time have effected the establishment of large numbers of seedlings and saplings, but here its benefit ended, for with continued fire-protection a dense and largely evergreen undergrowth takes possession of the ground, while in many places a luxuriant growth of climbers forms an impenetrable mass: the nature of the undergrowth is illustrated in Figs. 34, 35, and 36. Much sal seed fails to reach the ground through this dense matted undergrowth, but a considerable quantity reaches the ground and germinates, the seedlings persisting sometimes for a few years. Throughout these moist forests, however, for all practical purposes no established sal reproduction is to be found where fire-protection has been in operation for any length of time. It was hoped at one time that repeated cleanings would effect the establishment of existing seedlings, and these operations were carried out in some cases for five consecutive years, abundant light being admitted. This, however, had no effect, the seedlings showing no progress, although seedlings grown in ploughed land outside the forest in this region show remarkably rapid growth and do not ordinarily die back. Even on an experimental cleared line through the forest natural seedlings failed to establish themselves. This pointed to the adverse factor being not want of light but an injurious soil-factor, presumably connected with bad soil-aeration brought about by an excess of moisture and organic matter in the soil, the result of the altered conditions produced by continued fire-protection. Attempts to establish natural reproduction by the admission of light, which only intensifies the dense undergrowth, and by intensive cleanings, having failed, other measures, the object of which is completely to alter the soil conditions, have had to be devised. In the moister types attempts to burn the undergrowth are of no avail, since it will not burn satisfactorily. Cutting and burning it has proved little better: in many places it only results in a dense regrowth of weeds and climbers, while even where there is a tendency towards the replacement of the dense undergrowth by savannah grasses the process is slow and costly. It has therefore been decided to regenerate by means of clear-felling, cultivating for two years or more with field crops, and sowing up artificially with sal. So far this treatment is only in the experimental stage, but it gives good promise of success. It is, however, limited by the number of cultivators available, and hence for the present it is being confined

to the moister types of forest ; in the drier types where *sau* grass (*Pollinia ciliata*) is the chief soil-covering and burning is to a large extent possible, the grass is fired annually in the hope of eliminating it and causing the appearance of savannah grasses, in which sal reproduction will have a better chance of establishing itself.

(h) *Indicator plants and nurses.* Apart from grasses and the nurses already mentioned, there are certain other plants which indicate soil conditions suitable for the reproduction of sal or which assist in its establishment. One of the most characteristic of these is *Flemingia Chappar*, a gregarious leguminous undershrub reaching a height of about 3 to 6 ft. It is indicative of fairly moist fresh soil, often with a clayey tendency : its cover is light, and the ground beneath it is often bare. Under it sal seedlings are often found in quantity, and they appear to have no difficulty in making their way through it : where it occurs it is an almost certain sign of the presence of sal reproduction where there are seed-bearers in the vicinity. The same applies to *Indigofera arborea*, a leguminous shrub 4-8 ft. high, which is very common in the sal forests of Singhbhum and other parts of Chota Nagpur. *Clerodendron infortunatum* is an undershrub forming dense masses, usually in rich soil under shade : it is immune from damage by grazing, and kills out grass. Where it is dense sal seedlings are unable to survive under its shade : after occupying the ground for some time, however, it thins itself out, and as it is a good soil-improver and provides a good germinating bed, sal seedlings are often found in great abundance under it when it has reached the stage of opening itself out. *Woodfordia floribunda* acts as a useful nurse to sal on abandoned clearings, particularly in dry localities. On these clearings it soon takes possession of the ground. It resists frost and grazing, and under its light shade sal reproduction appears and is protected from drought, frost, and cattle. The sal makes its way through the *Woodfordia* and eventually kills it out. Thus sal pole crops which have sprung up on abandoned cultivation often have remnants of an undergrowth of *Woodfordia* which is gradually dying out.

The presence of numerous sal seedlings under other plants, however, is by no means always a sign that these plants are favourable to the establishment of sal reproduction. One of the most striking examples of this is seen in the case of *Macaranga denticulata*, a moderate-sized fast-growing euphorbiaceous tree common throughout the moist parts of the Bengal Duars. It has remarkable power of invading savannah tracts when fire-protection is introduced, and killing out the grass. For a time the ground may remain bare under it, but eventually ferns and an evergreen undergrowth make their appearance, while shade-bearing evergreen tree species establish themselves under its shade and in time supplant it. In the earlier stages of the existence of a crop of *Macaranga*, before the evergreen undergrowth takes possession of the ground, sal seedlings are sometimes found in quantity and may persist for several years in places where the drainage is good. Fig. 49 gives some idea of the profusion with which sal seedlings may sometimes occur under it. Such instances, which are exceptional, are to be found in a few places where the drainage is particularly good. Yet they have led to the belief that *Macaranga* is an excellent nurse for the sal. It should be noted that in the Duars sal seedlings growing in the open under favourable conditions do not

die back, but shoot straight up from the seed and become established saplings in a few years. The reproduction, both of sal and of *Macaranga*, shown in Fig. 49, sprang up on a fire-line abandoned eight years previously, and if the sal had not remained under the faster growing *Macaranga* it should have reached a height of nearly 30 ft. Instead of this, owing to the unfavourable conditions produced by the *Macaranga* it actually consisted of numbers of thin whippy shoots up to 2 ft. high which had died back repeatedly and which sprang from thickened root-stocks evidently dating from the time when the fire-line was annually cleared and burnt. The sal in this instance was undoubtedly older than the *Macaranga* suppressing it. In all other similar instances examined the suppressed sal was found to be as old as or older than the *Macaranga*. In one case sal and *Macaranga* were sown together eight years previously: the *Macaranga* had reached a height of 30 to 35 ft., while the few sal plants which survived had thin whippy shoots not more than 3 to 4 ft. high. A careful search throughout the Duars did not reveal a single vigorous established sal sapling under the cover of *Macaranga*. Thus under natural conditions in the Duars it cannot be said that *Macaranga* is of any benefit to sal reproduction, but decidedly the reverse. It is quite possible, however, that owing to its wonderful power of killing out rank savannah grasses it may yet be put to a useful purpose as a stage in the establishment of sal reproduction; if so it will be necessary to cut it out at the earliest possible opportunity, otherwise the sal will fail to establish itself.

Bamboos, provided their cover is open, are not inimical to the establishment of sal reproduction, but dense bamboo cover is harmful. Experimental sowings under the somewhat dense shade of a plantation of *Bambusa burmanica* near Dehra Dun resulted in failure, even where the soil was well aerated by hoeing up. The seedlings survived the rainy season without dying back, but gradually died off subsequently. The adverse factor here was apparently want of light, since a few seedlings towards the edge of the plantation survived. In flowered bamboo areas, both of *Dendrocalamus strictus* and *Bambusa arundinacea*, the dense young bamboo growth quickly suppresses any sal seedlings. Once the young bamboo growth has had a start little can be done to keep it in check without undue expenditure. Experiments in Burma have shown that the most effective method of keeping bamboo reproduction in check is to deal with the clumps during the year of seeding. The flowered area is fire-protected until the seed has ripened and fallen, and then burning is carried out late in the hot season; even thus only a portion of the seed is destroyed, and burning has to be repeated in subsequent years.

The natural reproduction of sal in grassy savannahs has already been alluded to, and it has been noted that of all the grasses in sal tracts *Saccharum Narenga* is the one most favourable to the establishment of natural reproduction. Sal seedlings are sometimes found in abundance under *Anthistiria gigantea*; although this grass has a somewhat dense cover there is usually an expanse of clean bare soil between the clumps, on which the seedlings are able to thrive. It has often been observed that in favourable seed-years seedlings spring up in greater quantity after a fire than on unburnt savannah land, where the dense growth of grass probably prevents much of the seed from reaching the ground; the burning of grass-lands near seed-bearers in

a good seed-year is therefore a useful measure. A characteristic feature of grass-lands adjacent to sal forest is the manner in which natural reproduction of sal appears round the edge of the forest and tends to spread gradually into the grass-land. In the savannahs of northern India sal reproduction is often preceded and aided by natural nurses which kill out the grass, reducing the danger from fire and serving to protect the young sal from frost. Of these some of the most important are *Mallotus philippinensis*, *Eugenia operculata*, *Lagerstroemia parviflora*, *Holarrhena antidysenterica*, and *Miliusa velutina*. In many savannah tracts frost is one of the greatest hindrances to the establishment of natural reproduction, particularly where air circulation is deficient.

(i) *Seasonal variations.* Apart from the all-important factor of the timely commencement of the monsoon rains at the time the seed falls, there are other climatic factors which influence the establishment of natural reproduction. These factors, which apparently depend on seasonal variations, no doubt act differently in different localities and types of forest. They have as yet been insufficiently studied, but such instances as have come to notice, in which they have operated, indicate that they may be of great importance, so much so that other conditions being equal they may be the deciding factor in regenerating in one year considerable tracts of forest where natural reproduction has been a failure for many years. Two instances of this may be quoted from the United Provinces, one affecting the sub-Himalayan forests and the other the plains forests of Gorakhpur.

Over a considerable part of the sub-Himalayan tract the year 1913 was one of the most successful seed-years within the memory of man. I visited some of the sal forests of this tract in February 1914 and found the most prolific reproduction, even in tracts where there had been little or no reproduction within the past thirty or forty years. In the Lakhmanmandi forest, consisting of more or less even-aged sal forest approaching maturity, but in which little or no reproduction had hitherto appeared, the ground over the whole block, some 400 acres in extent, was thickly carpeted with sal seedlings, which were so thick in parts as to hide the ground completely. Similar prolific reproduction was noticeable in the adjoining Sunmanthapla block. An old inhabitant of the Mundal valley remembered similar prolific reproduction about forty years previously. Some open fields were abandoned about that time, and became covered with a plentiful crop of sal seedlings. The site of these fields is now marked by a dense even-aged sal pole crop. Now the seeding and climatic conditions of the year 1913 were somewhat abnormal. A prolific seeding of the sal was accompanied by an abnormally early break of the rains about the middle of May instead of the end of June or beginning of July. This early commencement was followed by an abnormally early cessation of the rains, in the first half of August. The survival of vast quantities of vigorous seedlings up to the following February indicated that climatic conditions were specially favourable. The abnormally early break of the rains was certainly a favourable factor in ensuring successful germination; it is possible, but not certain, that the early cessation of the rains may have prevented the dying off of seedlings through an excess of soil moisture. Too much stress, however, should not be laid on the supposed beneficial effects of this early cessation of the rains, since the rainfall figures of Gorakhpur,

quoted below, show an abnormally heavy rainfall in August 1910, a year of very good natural reproduction. The normal rainfalls at Ramnagar and Gorakhpur are 62 and 48 in. respectively. This instance indicates that a period of about forty years probably elapsed between two years in which reproduction was as successful as it was in 1913.

The case of the Gorakhpur forests is also of interest. In the years 1897 and 1898 Mr. Clutterbuck was in charge of these forests, and at that time the state of natural reproduction was the cause of much concern, since, although a thorough search was made, not a single recent sal seedling could be found throughout the forests. These forests were revisited by Mr. Clutterbuck in my company in 1913, when natural reproduction in abundance was found everywhere except in certain heavily-grazed or badly-drained areas. Much of it dated from the year 1910, an exceptionally favourable seed-year in that locality, but some of it was older. The only apparent variable factor, other than climatic, which might have accounted for this sudden influx of sal seedlings, was the effect of fire-protection, but this must be ruled out, partly because fire-protection had been introduced as far back as 1875, and partly because in 1913 recent seedlings were found in abundance on burnt fire-lines and other burnt areas. The inference is that after many years of failure natural reproduction suddenly appeared in abundance owing to specially favourable climatic conditions combined with a good seed-year. The year 1910 certainly was an abnormal one so far as rainfall is concerned. The following statement gives the rainfall at Gorakhpur, month by month, in 1910 and 1911, and the normal, representing the average of forty-seven years :

Rainfall (in inches) at Gorakhpur ; normal, 1910 and 1911.

	January.	February	March.	April.	May.	June.	July.	August.	Septem ^r	October.	Novemb	Decemb	Annual
Normal	0.68	0.55	0.34	0.42	1.27	7.28	13.17	12.99	7.68	3.25	0.09	0.14	47.86
1910	0.30	0	0	0.03	2.63	11.59	11.34	30.13	4.57	3.35	1.30	0	65.24
1911	1.11	0	1.75	0	0.41	8.34	3.75	20.07	18.08	3.99	0.96	0	58.46

These figures show an abnormally heavy rainfall in May and June 1910, which undoubtedly created conditions very favourable to germination. Whether or not the heavy rainfall of August 1910 exerted a beneficial influence is difficult to say, but the heavy rain in November 1910 and January and March 1911 probably helped to prevent mortality from drought.

These two instances serve to indicate that local climatic conditions may be of great importance in the establishment of natural reproduction : they also indicate that the combination of an abundant seeding with climatic conditions ideal for the locality is of much rarer occurrence than might be supposed. The importance can thus be realized of taking every advantage of such favourable years as do occur for aiding the establishment of natural reproduction, where it is wanted, in areas where it does appear. A study of local climatic conditions as affecting sal reproduction in different regions would no doubt yield interesting results. It is probable that the effects vary considerably in dry and moist regions respectively. As an instance of the local

effect of seasonal variation, it is reported that in the Gorakhpur district during the hot season of 1914 east winds prevailed instead of the scorching *loo*, with the result that an unusually large proportion of the seedling crop survived without having died back at all.¹

ARTIFICIAL REPRODUCTION. As a general rule the natural reproduction of the sal is so good where conditions are favourable that artificial reproduction has not hitherto been carried out on an extensive scale. In future, however, it is likely to be carried out very largely in tracts where sal is capable of growing well but where the conditions for natural reproduction are adverse. This is particularly the case in the moist forests of the Duars, where continued fire-protection has so altered the soil conditions that natural reproduction is now out of the question throughout the greater part of the tract, and artificial reproduction is contemplated on a large scale. The afforestation of grassy blanks by artificial means has received considerable attention in recent years, particularly in the United Provinces. There is also little doubt that when more concentrated methods of regenerating sal forests become the rule, artificial reproduction will be much more general than it has been hitherto; Mr. Hole's experiments in the Dehra Dun forests show that artificial sowings on hoed ground in narrow cleared strips protected by side shade, and weeded during the first year, result in the rapid establishment of seedlings without dying back, whereas the establishment of natural reproduction in the same locality is a much slower process. This system, however, has been found to be useless in the moist forests of the Bengal Duars, where the excessive damp causes the seedlings to die off on narrow cleared lines through the forest.

In any system of artificial reproduction it is essential that fresh sal seed should be collected as soon as it falls to the ground and sown immediately, since it retains its vitality for a very short time. In artificial sowings, as in the case of natural reproduction, success must depend largely on the timely commencement of the monsoon rains unless watering can be carried out.

Various attempts in the artificial restocking of blanks with sal have been recorded in different localities in the past. The majority of these have resulted in failure or only partial success. In some cases want of success has been due to the fact that attempts have been made to restock blanks which are unsuitable for the growth of sal, or in which sal is able to establish itself slowly and only partially owing to adverse factors such as frost, drought, bad drainage, &c. The chief factors favourable to the establishment of sal seedlings have been indicated under 'the seedling': where these factors are not present sal will either fail to establish itself or the process of establishing itself will be lengthy, and success may at the best be only partial. Unless the rapid establishment of the young plants can be assured the prospects of financial success are at least doubtful. Attempts at artificial reproduction so far have included both direct sowing and transplanting, and some instances of both may be quoted.

Dehra Dun experiments. Various experiments in the artificial reproduction of sal have been carried out at Dehra Dun. Transplanting nursery-raised seedlings during the first rains with balls of earth proved quite successful. Irrigated line sowings, in which the seed was sown along the side of the water-channel and between it and the ridge of earth thrown up alongside it, gave good

¹ Annual Forest Administration Report, Eastern Circle, United Provinces, 1913-14.

results, particularly where regular weeding was carried out. Unirrigated line sowings were successful if protected by regrowth of other species along either side of the line, the line itself being kept clear overhead and well hoed. If completely exposed all round the seedlings suffered from frost in the winter. Line sowings with field crops proved a cheap and easy method of raising sal, but the seedlings suffered much from frost in the winter and from drought throughout the dry season. Possibly keeping the cleared lines narrow, say 1-1½ ft. wide, and leaving high stubble on reaping the crop, might afford more protection. The crop employed was the lesser millet or *mandwa* (*Eleusine coracana*, Gaertn.). It was found better to sow the sal along lines kept clear of crops to a width of about 2 ft., the crops being sown in the intervening spaces, than to sow the crops continuously over the area; in the latter case the seedlings lacked vigour, and quickly succumbed to drought after the reaping of the crops in October.

Experiments were carried out with line sowings of sal between a double line of nurses sown at the same time, with the object of ascertaining if sufficient protection from frost and drought could be afforded to the sal seedlings by the nurses on either side, and if any particular nurse possessed special qualities in this respect. Seven different nurses were tried, the lines of nurses being sown 3 ft. apart, with a line of sal between them. The following observations were recorded regarding the different nurses tried: (1) *Holarrhena antidysenterica*, not sufficiently protective, the leaves falling early in the hot season and exposing the sal, which died back from drought; (2) *Mallotus philippinensis*, a good nurse where it survived, but where it suffered from drought the sal died back from drought, though subsequent growth was good; where protected by the nurse the development of the sal was good; (3) *Bauhinia racemosa*, a good nurse; where protected by the nurse the sal suffered no damage from frost, though in places along the lines where the nurse was absent the sal seedlings were killed back; (4) *Eugenia Jambolana*, unsuitable for growing in the open, as it suffers from drought itself; (5) *Eucalyptus crebra*, itself suffered a good deal from drought, but formed a sufficiently dense cover to protect the sal from frost, and proved a good nurse, the sal growing vigorously; (6) *Ougeinia dalbergioides*, growth too slow to afford protection if sown the same year as the sal; (7) *Ricinus communis* (castor-oil plant), protected the sal well from frost and drought in the first two seasons, but afterwards became too tall and lanky to be an efficient protection.

These experiments indicated that with the exception of the castor-oil plant better results would have been obtained by sowing the nurses a year or more in advance of the sal. In localities suitable for the growth of the sal, but in which the sal suffers in youth from frost or drought, there seems to be good scope for experiments in sowing it between lines of suitable nurses provided these have been introduced at least a year beforehand, in which case a distance of 3 ft. between the lines of nurses would probably be too little.

United Provinces. In the Ramnagar forest division various records exist of sowings in open grass-lands ploughed up prior to sowing: most of these have proved unsuccessful owing to damage from frost. The most important attempt was made over an area of 25 acres at Chopra on an open grassy bank on abandoned cultivation: the area is situated close to the base of the outer

Himalaya on poor soil with a subsoil consisting of a deep boulder deposit. Sal seed was sown about 1878 to 1880 in ploughed lines 15 ft. apart, and other species were sown later to fill up gaps. In the earlier years the plantation was artificially irrigated by water-channels, but the young plants were killed back by frost or drought for some years. In 1910 the lines were distinctly visible, though somewhat patchy: the trees had a height of 20 to 30 ft., which though not good for an age of about thirty years, is perhaps as satisfactory a rate of growth as might be expected in such an unfavourable locality. Sowings made at the same time on old fields at Khushkundli in the same division were more successful, the trees having attained a height of 20 to 30 ft. in fifteen years.

Sowings were made in 1907 and 1909 on deserted fields at Ghatura in the same division. The land was ploughed and the seed was sown broadcast, with the result that a thick crop of seedlings came up, and had reached a maximum height of 2 ft. in three years. The area became covered with a thick growth of grass, and the seedlings were killed back annually by frost; by 1914 they had made no appreciable progress.

The restocking of the large grassy tracts, locally known as *phantas*, in the North Kheri forests was commenced on an experimental scale in 1905, and sowings in lines have been found to give good results. The tall grass, chiefly *Saccharum Narenga*, is burnt in January or February, and the ground is hoed up in lines $1\frac{1}{2}$ ft. wide and 6 to 8 ft. apart, the seeds when ripe being sown several inches apart along the lines. Weeding and hoeing along the lines is carried out for two years after sowing, in order to aerate the soil and promote vigorous growth: the area is also carefully fire-protected. The development of the young plants is by no means rapid. Sowings combined with the raising of field crops would probably give better results, but the supply of agricultural labour is insufficient to allow of this on any scale.

Transplanting nursery-raised seedlings with balls of earth has given variable results, but owing to the length of the taproot and the great care necessary in transplanting, this method is likely to prove too costly and not sufficiently successful for adoption on a large scale. The Shirpur plantation at Simaria in the Pilibhit district was formed in this way. Part of it was formed in 1893 and part in 1908. The seedlings used were pricked out twice in the nursery and transplanted when three years old: they were lifted with balls of earth about $1\frac{1}{2}$ ft. deep and the protruding ends of the taproots were cut off. After transplanting the plants were for a few years watered in the dry season and protected from frost in the winter by cowls of grass. Subsequent growth is reported to have been good.

Mr. R. G. Marriott has obtained successful results by transplanting nursery-raised plants two and three years old after pruning the taproots to a length of 18 in. and the stems to about 1 in. from ground-level. The experiments were carried out in the Gorakhpur district in 1915 and 1916 with seedlings raised from seed sown in nursery-beds in 1913; over 3,000 seedlings were transplanted to the forest, and it was found that with care in transplanting success could be obtained to the extent of over 90 per cent., although no watering was done after transplanting. The best results were attained with strong vigorous plants with thick stems, their size rather than their age

being the determining factor. For this reason plants three years old gave better results on the whole than those two years old. Regular weeding, loosening of the soil, and watering in the nursery, in order to stimulate vigorous growth, is thus of great advantage. The plants may be grown fairly close together, and should not be pricked out in the nursery, as encouragement should be given them to produce healthy taproots and not lateral roots.

It was found advantageous to dig the planting holes a few months in advance, say about February, in order to allow the earth dug out of them to become well aerated and to allow rain-water to enter the holes and moisten the soil below them. The best season for transplanting was found to be as early in the rains as possible, that is, as soon as the ground became thoroughly saturated by the first heavy rain. If transplanted later the plants produced weakly shoots. In transplanting the best results were obtained by digging up the plants in the nursery in the evening, pruning them, and keeping them overnight with their roots embedded in soft mud in a trench, and transplanting them in the forest in the cool of the following morning. Before planting all dead leaves should be removed from the bottom of the pit, in order to prevent the accumulation of deleterious organic matter and the sinking of the earth after being filled into the hole. While the earth is being filled round the plant it is very necessary that it should be pressed down round the roots; failure to do this was found to cause the death of the seedlings owing to their becoming loose in the holes or to the earth sinking and allowing water to accumulate in the depression so created. Subsequently it was found advisable to keep the seedlings clear of suppressing weed-growth and to loosen the soil round them periodically.

Plants pruned in this way sent up new shoots not long after being transplanted, and on being dug up were invariably found to have produced new taproots arising from close above the point of pruning. It was noticed that plants with small shoots already springing from the base of the stems grow more quickly than others, which suggests the possibility of obtaining good results by pruning down the stems some little time before removing the plants from the nursery, in order to encourage these basal shoots.

The transplanting of natural forest seedlings in the same way, after pruning their stems and roots, was also tried, but the results were far less successful than in the case of vigorous nursery-raised transplants.

So far as is known, the oldest sal plantation in the United Provinces is a small one in the compound of the club at Bareilly, which was formed in 1857. Fig. 50 shows a sal plantation 1.12 acres in area in the railway station yard at Gorakhpur. It was formed in 1887 or 1888 by transplanting young seedlings brought from the forest: these were watered in the earlier years. This plantation has been repeatedly thinned. Measurements made in the Bareilly and Gorakhpur plantations in 1916 and 1917 respectively are given below (p. 123).

Bengal. Artificial reproduction is destined to play a very important part in the regeneration of the moist forests of the Duars, which, owing to prolonged fire-protection, have been brought to a state in which natural reproduction is impracticable. Far from being a disadvantage financially, artificial reproduction is here likely to have a great advantage over natural reproduction in

that the rotation will be much more shortened, while the productivity of a very fertile forest tract will be utilized more intensively by plantations than by natural crops, in which sal is often scattered in groups of varying extent among numerous other species, many of which are of little or no value.

Two existing plantations, one in the Buxa and the other in the Jalpaiguri district, indicate the rapid rate of growth attainable by artificial crops in the Duars.

(1) Sal sowings on the southern boundary of the Buxa reserve. These sowings were made by Dr. (afterwards Sir William) Schlich between 1876 and 1880, a belt of sal 100 ft. broad being formed with the object of establishing a dense fire-belt. Measurements which I made in January 1915, the trees being then about thirty-seven years old, showed an average girth and height of 3 ft. 9 in. and 70 ft.; the maximum girth was 4 ft. 8 in. The locality here is, if anything, somewhat below the average.

(2) Sal sowings of 1896 and 1897 in the North Muraghat forest, Jalpaiguri. Two plantations, aggregating 12 acres, were formed in 1896 and 1897 by Mr. Haines and Sir Henry Farrington by direct sowing on a cleared area along with a crop of rice. The sal seed appears to have been sown in lines 10 ft. apart. In the earlier years pigs did much damage to the young plants. In the first year or two it was found advantageous to shade the plants in the hot season, and weeding and cleaning was found necessary in the earlier years in order to keep down the heavy growth of grass and weeds. For some years the plantation seems to have been lost sight of and was left untended, with the result that most of the stems became suppressed, chiefly by *Macaranga*, and in some cases they became congested for want of thinning. The plantation was in this condition when I visited it in January 1915, but the stems which had escaped suppression by *Macaranga* and had succeeded in becoming dominant showed remarkably good growth, the average girth and height of these stems being 2 ft. 5½ in. and 70 ft., and the maximum girth and height being 2 ft. 11 in. and 77 ft.; the age was then eighteen or nineteen years. This growth is probably slower than what might be expected in the case of a regularly tended and thinned plantation in the same locality. Measurements made in 1909–10, when the plantation was twelve or thirteen years old, showed an average girth and height of 1 ft. 9 in. and 55 ft., and a maximum height of 60 ft.

These two plantations indicate that if regular tending is carried out a girth of 6 ft. should be attained in the Duars in less than fifty years in localities of good quality, and in about sixty years in localities of fair quality. In natural crops, on the other hand, estimates from sample plot measurements indicate that a girth of 6 ft. is attained in 100 years in Jalpaiguri and 120 years in Buxa.

The rapid growth of artificially raised plants under favourable conditions is further exemplified in the plot of saplings in an abandoned nursery at Mendabari, measurements of which are given on p. 123 (see Fig. 41). In 5½ years an average girth and height of 9½ in. and 19½ ft. were attained; this, however, would hardly be possible in sowings on a large scale without excessive expenditure on preparation of the ground and tending. Past experiments in the moist forests of the Duars have shown that artificial reproduction cannot

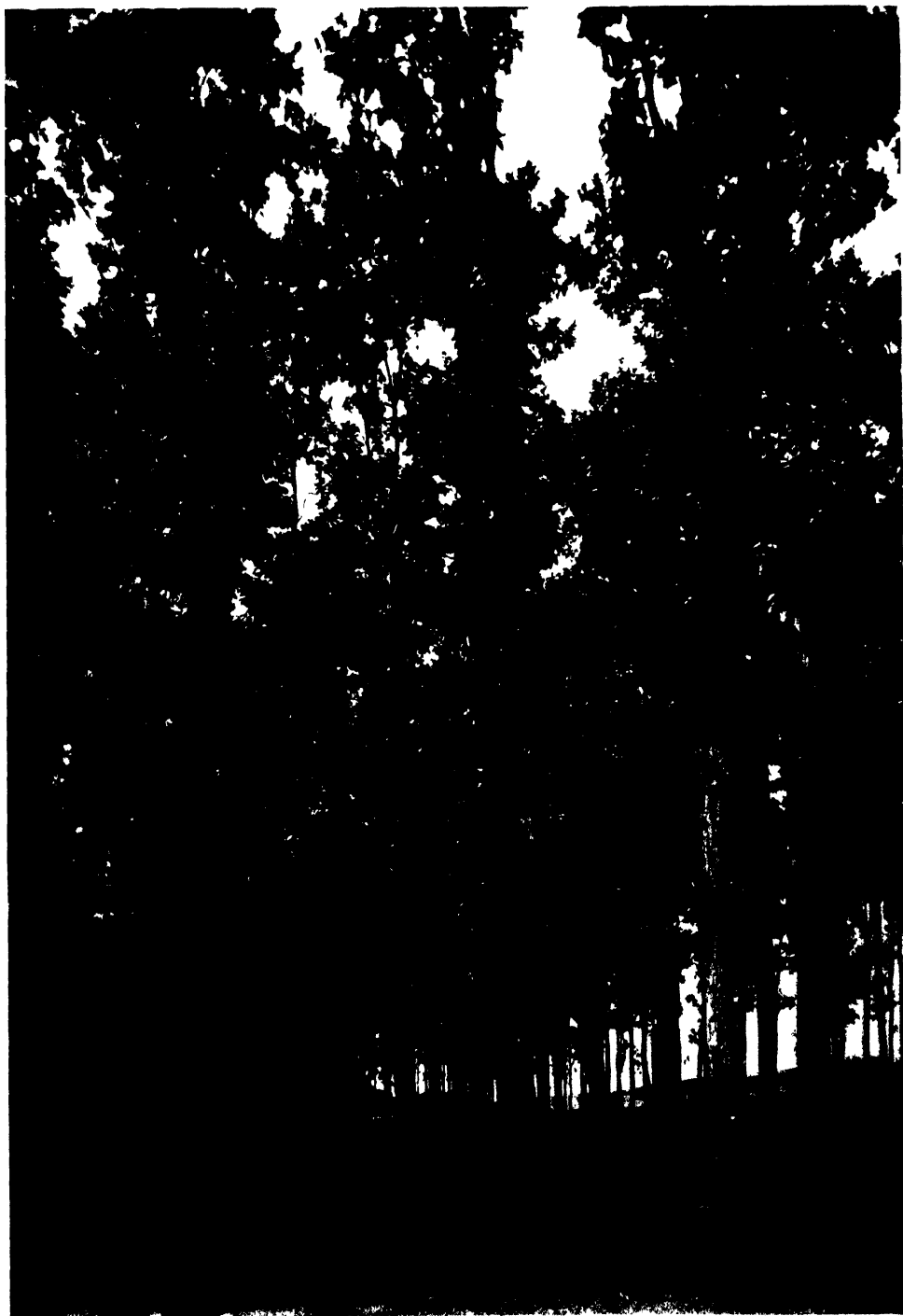


FIG. 50. Sal plantation 30 years old, Gorakhpur, United Provinces.



FIG. 51. Sal coppice-with-standards, immediately after cutting of coppice, Tikri forest, Gonda, United Provinces.

be effected by any system of introducing sal into existing crops. Sowing on strips 50 ft. or more in breadth cleared through the forest, which has proved successful in Dehra Dun, has been found to be quite unsuccessful in the Duars ; the seed germinates, but the seedlings die off even when kept weeded, owing to the excessive damp. Complete clearing of the forest growth, with burning of all refuse, is necessary in order to eradicate weeds and to aerate the soil. This operation can be carried out economically with the aid of shifting cultivation, and this system, somewhat on the lines of the teak *taungya* system of Burma, is now being introduced. Much experimental work remains to be done, but results so far have shown that sal sowings are not likely to be financially successful except on land actually under cultivation. That fallow grass-land can be ploughed up and successfully sown with sal has been proved, but the cost of ploughing to a sufficient extent and of subsequent cleaning to keep down the weeds has so far proved to be unduly high : if field crops are not cultivated it is found necessary to keep the ground clean by hoeing for the first two years. One of the chief dangers to be contended with in these sowings is the damage done by wild pigs, which are very destructive to the young sal plants, chiefly in the first two years : on this account careful fencing is necessary. Another source of damage is exposure to the sun in the hot season. The ground requires to be kept clear of weeds, but at the same time the young plants require side shade from the sun in the first year : experiments are in progress to effect this by leaving the stubble of the crops high on the south side of the seedlings and by heaping cut grass and weeds round the plants in order to conserve the soil moisture. It is coming to be recognized, however, that if the soil has been brought into a proper state of aeration protection from the sun is not necessary.

As regards the actual method of cultivation in the Duars, experiments carried out by Mr. E. O. Shebbeare so far have shown that the best results are attained by sowing the sal in lines 6 ft. apart, the seeds being sown as close together in the lines as their supply allows. The sal is sown with the first crop, and as many crops should be taken off the land during the first two years as possible, since this tends to keep the soil loose and to keep down the weeds. The crop found most suitable is the Garo mixture with cotton, which consists of *bhadoi* paddy, Indian corn, and cotton all sown together. After the paddy and Indian corn have been cut the cotton remains standing throughout the cold season. The Garos also put various minor crops in the mixture, such as sesamum, indigo, pumpkins, and chillies. If there is no cotton it is possible to obtain a crop of millet after the paddy is cut, and experiments in obtaining a crop of mustard are promising.

SILVICULTURAL TREATMENT. The silvicultural treatment of the sal may be considered separately under four heads : (1) coppice, (2) uneven-aged high forest, (3) even-aged high forest, and (4) tending operations in high forest crops.

1. *Coppice.* The system of coppice-with-standards has been employed more extensively in the plains forests of Oudh in the United Provinces than elsewhere, notably in parts of Bahraich, Pilibhit, South Kheri, and Gorakhpur, and in the Tikri forest of Gonda. It has also been employed to a limited extent in the Dehra Dun forests, where, however, the coppice often suffers

badly from frost. Coppice fellings are also carried out in parts of Bihar and Orissa, for instance in the Saitba working circle of Kolhan, on somewhat poor hilly ground, and in the Chandka and Khurda working circles of Puri.

In the United Provinces the tendency now is to abandon coppice-with-standards in favour of high forest. In the Dun this has been indicated by the fact that the coppice suffers so much from frost ; indeed coppice must be considered an unsuitable system for sal in areas subject to any but slight frosts. In the plains forests of Oudh the system of coppice-with-standards has been largely condemned owing to the immense damage done to the standards by the abnormal drought of 1907 and 1908. During these years of drought it was noticeable that standards over coppice suffered much more than trees in high forest crops (see Fig. 45). In places also the coppice failed entirely owing to the injury done by drought to the trees coppiced not long before they were felled (Fig. 42). Another cause of failure of coppice in some localities is the fact that many of the trees coppiced have been unsound and hollow, owing no doubt to burning and maltreatment in the past.

In the Oudh forests the rotation adopted for sal coppice has varied in the past from twenty to thirty years, and the number of standards prescribed to be retained has varied from 40 to 80 per acre. Experience has shown that a rotation of twenty years, which was formerly adopted in Gorakhpur, produces poles of small size only ; also that the retention of too many standards is unwise if good coppice-shoots are desired, since the standards if at all dense tend to suppress the coppice. Under ordinary conditions a maximum of forty standards per acre is probably quite sufficient.

In the Oudh coppice-with-standards coupes the young sal coppice has to contend at first with other species which shoot ahead of it. Among the chief of these are *Kydia calycina*, which may reach a height of 20 ft. in two years, *Cassia Fistula*, *Lagerstroemia parviflora*, *Grewia*, and to some extent *Terminalia tomentosa*. After some years the sal coppice overtakes these species, with the exception of the last named, which keeps fairly level with it. Hence if cleaning operations for the benefit of the sal coppice are considered necessary they can be carried out most advantageously during the first year or two. In the Tikri forest it has been found that cleanings carried out half-way through the rotation have little effect, since by that time the sal, if it has not already become suppressed, has outgrown its competitors. Figs. 51 to 55 show sal coppice-with-standards crops in different stages, and give some idea of the Oudh forests worked under this system. As a rule the coppice is easily distinguished from the standards for the first 10–15 years, but thereafter the distinction is not so apparent, and after about 20–25 years it is often difficult and sometimes impossible to distinguish the two except in the case of standards of large girth.

Details regarding the coppicing power of sal and the factors affecting it have already been given under 'silvicultural characters'.

2. *Uneven-aged high forest.* Until comparatively recently all the sal forests of India which were not worked as coppice or coppice-with-standards were treated as uneven-aged high forest and worked under some form of selection or improvement fellings. The reason usually given for adopting such fellings was that owing to past maltreatment the forests contained much



FIG. 52. Sal coppice-with-standards, coppice 1 year old, height chiefly 3 to 5 ft., occasionally up to 7 ft., West Lehra forest, Gorakhpur, United Provinces.



FIG. 53. Sal coppice-with-standards, coppice 2 years old, up to 15 ft. in height. West Lehra forest, Gorakhpur, United Provinces.

unsound, over-mature, and otherwise undesirable material which had to be removed in the interests of the future crop. So far as it goes this treatment is no doubt quite sound, but it takes account only of the existing crop, and ignores the question of obtaining sufficient reproduction. Fortunately the sal in many cases regenerates so freely that young crops would appear under almost any form of treatment, provided the canopy is opened sufficiently. On the other hand there are localities where regeneration is a more difficult matter, and selection or improvement fellings have entirely failed to secure it.

The truth is that selection and improvement fellings were adopted mainly owing to the fact that the silviculture of the sal was imperfectly understood, and they may be regarded as a provisional and temporary arrangement pending a more complete study of the habits and requirements of the tree. It will be sufficient to mention the fact that the sal was at one time looked upon as a shade-bearer and treated accordingly. We now know, as a result of the detailed experiments recorded above, and from observations generally, that this view is entirely fallacious, and that reproduction cannot be established satisfactorily unless the canopy is well opened out. The tendency of the sal to establish itself naturally in even-aged masses wherever conditions are favourable is a further reason why efforts should be made to produce these conditions and to bring up even-aged crops rather than to perpetuate systems of uneven-aged high forest which are not so well adapted to the requirements of the sal.

The selection and improvement fellings under which sal forests have been for the most part worked hitherto have been conducted on the usual selection system lines. For selection fellings a minimum exploitable girth is fixed, and the corresponding age or rotation is estimated. Each felling series is divided into a definite number of annual coupes corresponding to the number of years in the felling cycle, that is, the period during which fellings go once round the felling series. In the selection fellings the yield is fixed as a rule by number of trees, and in each annual coupe are felled sal trees of and above the minimum exploitable girth up to the number fixed for the yield. In addition improvement fellings are generally carried out with the selection fellings; these are intended to benefit the future crop by the removal of inferior species and otherwise undesirable stems interfering with promising stems of sal and other valuable species. Where improvement fellings only are prescribed, the yield is fixed by area.

In the working plans of the United Provinces the exploitable girth usually adopted has been 6 ft., the corresponding rotation varying from 120 to 150 years, and the felling cycle varying from 15 to 28 years. In Bengal the exploitable size has been fixed as a rule at 6 ft. girth or 2 ft. diameter, with a rotation varying from 100 to 150 years. In Assam an exploitable girth of 6 ft. has been in force in Goalpara and Darrang, the rotation being 120 years, and the felling cycle 15 years and 5 years in the two localities respectively. In Bihar and Orissa the Singbhum forests have been worked under the selection system with yield by area; the exploitable girth has been 6 ft., the rotation 180 years, and the felling cycle 30 years. In the Banpur working circle of Puri an exploitable diameter of 2 ft. has been adopted, with an estimated rotation of 120 to 150 years; the yield is by number of trees. In the Central

Provinces the exploitable girth usually adopted for selection fellings is 6 ft., the estimated rotation being 170 years; in most cases the felling cycle is 30 years. In the Khannat sal forests of South Mandla the exploitable girth is fixed at 5 ft.

3. *Even-aged high forest.* In order to produce successive age-gradations of even-aged crops, for which the sal is best adapted, some system of concentrated regeneration is necessary. The general outline of such a system is the one applicable to the conversion of irregular forest crops of any kind, such as those usually found throughout India, into even-aged high forest crops. The general scheme is to divide the ascertained rotation into a number of regeneration periods and to divide the forest area into a similar number of periodic blocks. One periodic block, usually termed block I, is selected for regeneration during the period, while subsidiary fellings of the selection type, with thinnings, are prescribed over the remainder of the area under a definite felling cycle. Under this system each block is regenerated in turn, until by the end of the rotation a series of more or less even-aged crops is obtained. It is not always necessary, or even advisable, to allot all the blocks to periods, but in some cases it may be advisable to allot at least some of them.

The general outline of the scheme is simple enough, but the allotment of crops to periods may present difficulties if the forests are in a very abnormal condition. In the case of the sal it is generally advisable to allot to periodic block I those compartments which contain a large quantity of established natural reproduction which is in need of freeing; this is particularly advisable in localities where the steps necessary to obtain reproduction have not been sufficiently determined by experiment. In addition, however, it may be necessary to allot for regeneration areas which contain little or no established reproduction, and it is here that difficulties will be encountered and the factors of the locality will require careful study. The various factors which influence the reproduction of sal, and the measures necessary to secure its establishment, have already been described in some detail so far as they are known at present. The more important considerations involved may be recapitulated briefly:

1. Favourable or unfavourable soil conditions are indicated by the growth of certain plants, notably grasses, of which *Saccharum Narenga* is an indicator of favourable conditions.

2. As regards seed-bearers, the size and soundness of the trees appears to have no effect on the fertility of the seed, though trees with well-developed crowns may be expected to produce seed in greatest quantity. Seed-years are fairly frequent in most localities, but a combination of prolific seeding with favourable climatic conditions is of rarer occurrence than might be supposed. The fruits ripen chiefly in June, and are ordinarily carried to a distance of 50–100 yds. from the tree, though possibly an espacement of more than about 50 yds. between seed-bearers, giving a radius of seeding of 25 yds., should not be relied on to produce a plentiful crop of seedlings.

3. A thick layer of dead leaves has an adverse mechanical effect in entirely preventing germination in the open, while in the shade it produces shallow-rooted seedlings which succumb after the first rainy season; the removal of a layer of dead leaves, by burning or otherwise, is therefore an advantage where reproduction is desired.



FIG. 54. Sal coppice-with-standards, coppice 8 years old, mean height 17 ft., maximum height 26 ft.,
West Lebna forest, Gorakhpur, United Provinces.



FIG. 55. Sal coppice-with-standards, coppice 20 years old, about to be cut, mean height 37 ft.,
Tikri forest, Gonda, United Provinces.

4. Germination takes place under fairly dense shade, but the resulting seedlings do not survive, primarily owing more to an unfavourable soil factor than to the direct effect of shade.

5. An important consideration in the establishment of reproduction is the dying back of seedlings, which is due to various adverse factors such as bad soil-aeration in the rainy season, drought in the dry season, frost in frosty localities, and mechanical injury from animals, insects, fire, &c. In the case of the first two factors the remedy is to promote vigorous growth, particularly of the taproot, in the first rainy season: this goes a long way towards ensuring the survival of the seedling in the subsequent dry season. In the sal forests of the semi-moist type of Dehra Dun and many other localities with a loamy soil this can be effected by digging up the soil, removing the dead leaves by burning or otherwise, completely removing the overhead canopy, and weeding the young crop.

6. Where frost or drought are to be feared, protection from the side is of more value than overhead cover: it has been found that overhead cover which is dense enough to cause the suppression of young sal plants may be insufficient to protect them from injury by frost. In the Dehra Dun forests excellent reproduction has been obtained by clear felling in patches or strips not more than 100 ft. and preferably not more than 60 ft. wide, removing dead leaves, digging up the ground, sowing sal seeds, and weeding the seedlings during the first season. The most favourable direction of strip fellings has yet to be determined, and it may possibly be found to vary locally. In Europe lateral protection from the morning sun, that is, from the south-east, is perhaps the most effective in preventing damage from frost; in the Dehra Dun forests complete protection was obtained on a cleared strip running ENE. to WSW.

7. The opening of the canopy, however, will not effect the establishment of natural reproduction in all types of forest. In the very moist types found in the Bengal Duars and Assam the admission of light produces a rank growth of weeds and climbers, which prevents the establishment of reproduction (see Figs. 47 and 48). In the semi-moist types found throughout the greater part of the United Provinces and elsewhere, other conditions being favourable, the admission of light sufficient to cause a moderate growth of grass will induce the appearance of sal reproduction, the establishment of which depends on a drastic opening of the canopy.

8. In dry forests where reproduction is difficult to obtain two methods have been suggested with the view of preserving the soil-moisture, (a) the introduction of an underwood as a soil-protection, and (b) cultivation of the surface soil, accompanied if necessary by mulching in the dry season and the construction of trenches and small embankments in order to arrest the run-off of water.

9. In the case of mechanical injury from fire, grazing, &c., which prevents the establishment of reproduction, protective measures are necessary. Mere closure to grazing may be sufficient to induce good reproduction, but where the soil has become hardened by trampling, thorough digging up of the soil, accompanied by a severe opening of the canopy, has proved effective in producing conditions favourable for reproduction.

These are some of the main considerations involved in devising means of

regenerating definite blocks of forest with the object of producing even-aged crops. The advisability of taking advantage where possible of existing young crops already established on the ground, and freeing them from overhead cover, cannot be emphasized too strongly: this important step should be taken as a primary measure, efforts to induce the appearance of new reproduction being considered as supplementary. In this connexion there is little doubt that artificial reproduction will be more largely resorted to in the future than has been the case in the past. In certain types of moist forest it will be impossible to obtain satisfactory reproduction in any other way than by clear-felling, burning, and regenerating artificially, preferably by the aid of temporary cultivation with field crops; this applies not only to the moist forests of the Duars, but also to moist types found in other localities, for instance in fertile valleys and ravines where any opening of the canopy is at once followed by a dense growth of weeds and climbers. The restocking of grassy blanks furnishes another instance where artificial reproduction may have to be resorted to on a large scale.

The degree to which the canopy should be opened in order to stimulate sal reproduction, and the manner in which the opening should be carried out, are matters of great importance which must be decided by local experience. The excellent reproduction found throughout a considerable portion of the Singhbhum forests is attributable in many cases to heavy fellings carried out for the production of sleepers in 1895 and subsequent years. It is proposed to introduce concentrated regeneration fellings in these forests, and over considerable areas these fellings will consist of nothing more than the removal of the overwood over young crops already well established. In the high-level forests of North Kheri in the United Provinces some of the finest pole crops now existing are to be found in areas where heavy fellings were carried out many years ago. In the neighbouring district of Bahraich an experiment in the drastic opening of the canopy was carried out about 1885 at Tigra well. Only about twenty trees per acre were left, the remainder being felled. The result was that over a considerable portion of the area reproduction failed, a sea of grass resulting. In some places, however, vigorous and extremely dense pole crops of sal have resulted. In all probability these crops arose from natural reproduction already on the ground, in which case this experiment would show that whereas the removal of the canopy greatly stimulates the growth of young sal crops, it cannot be relied on in itself to effect the establishment of new reproduction, and may result in nothing more than a heavy growth of grass.

The question of opening the canopy in the form of fellings in clear narrow strips has already been alluded to in connexion with Mr. Hole's experiments in the Dehra Dun forests. The experiments of 1915 were carried out in a particularly unfavourable year, owing to the heavy rainfall in August and September and an unusually hot dry season following. Sowings in the open without side shade resulted in only 2 per cent. of healthy seedlings at the close of the year, sowings in the shady forest resulted in 6 per cent., while sowings in cleared lines and patches 60–100 ft. wide resulted in 36 to 42 per cent. A clearing 180 ft. square gave only 26 per cent. of successful seedlings, which indicates that in these forests an opening more than perhaps 100 ft. wide is not

advisable. The local application of strip fellings in actual practice will involve (1) ascertaining by trial the direction of strip which promotes the most successful establishment of reproduction, with the aid of side protection if required, (2) laying out comparatively narrow cutting sections, if possible with their long sides parallel to the strips, and (3) working completely through these cutting sections during the regeneration period by successive parallel strip fellings, the intervals of time between the successive strip fellings being long enough to enable the young growth to become sufficiently tall to escape damage from ordinary frosts. The regeneration period should be long enough to enable the young growth in the first strip to reach a height sufficient to afford protection to the strip which will be felled at the end of the period in the adjoining cutting section. To take an example, with a regeneration period of 30 years, intervals of 10 years between successive strip fellings, and strips 60 ft. wide, the width of the cutting sections would require to be 180 ft. Alternatively shelter belts may be left between the cutting sections to be felled and regenerated later, or the cutting sections may be placed in different periods, but neither of these alternatives is to be commended if they can possibly be avoided, owing to the diffusion of work and complication which they would entail.

It is many years since the value of side protection from frost, as obtained by fellings in narrow strips, was discovered in the case of the sal. Writing in 1885,¹ Captain E. Wood, Conservator of Forests in Oudh, described experiments carried out in the coppice forests of Bhira, where somewhat severe frosts are experienced. These plots were coppiced : (1) two acres completely cleared, (2) two acres cleared in strips 20 ft. broad, leaving alternate strips 20 ft. broad untouched, (3) one acre cleared of about half the stock, the remainder being left in the form of standards. In plot 1 the first severe frost greatly damaged the coppice-shoots, in plot 2 the shoots grew up straight and were untouched by frost, while in plot 3 they suffered from suppression by the standards.

In the Central Provinces also strip fellings have apparently been tried with success. In the Lormi range working plan, Bilaspur, 1898, it is stated : ' Clear strip fellings have been tried in this division with very excellent results.'

Mr. Hole's experiments in the Dehra Dun forests have revealed the fact that the direction in which cleared strips run has a very decided influence on the establishment of the young crop. He found that in years of heavy rainfall side shade on the south is injurious in keeping the soil continually moist and causing the plants to suffer from bad soil-aeration and from the attacks of leaf fungi. He advocates, therefore, that in localities in northern India with a normal rainfall of 50 in. or more during the period June to September inclusive the strips should run in a true north and south direction, thus ensuring shade on the area in the morning and afternoon and full sunlight in the middle of the day, which will prevent an excessive accumulation of moisture in the soil. Under such conditions the system he advocates for regenerating a given area is to divide it permanently into a series of narrow strips running north and south, the width of the strips being about three-fourths the height of the surrounding forest crop. Every alternate strip will be clear-felled, hoed up, and sown thickly with sal seeds, not less than six seeds to the square foot,

¹ Ind. Forester, xi (1885), p. 436.

the resulting young crop being weeded as often and as long as may be found necessary. In the case of narrow clearings, where weeds are less abundant than on wide clearings, one weeding at the end of the first rains and one at the end of the second rains has been found sufficient. When the young crop has attained full height-growth the intervening strips will be felled and regenerated in the same way. He estimates that the time required to produce a full crop of established seedlings $3\frac{1}{2}$ ft. high on a strip treated in this way will be five years, while a similar result could not be obtained by a system of regeneration under a shelter wood, supplemented by the clearing of dead leaves from the surface of the soil, in less than forty-eight years.

This system is not intended to apply to open poorly-stocked areas, or to localities where bad soil-aeration is not a factor of importance, or where there is no fear of frost damage, as in the Duars or Assam, where large clearings are possible. The system is intended to apply to average well-stocked sal forest on loam, in places where frost damage is feared, where dying back is a marked characteristic, and the establishment of seedlings is slow and uncertain: such conditions are probably met with in the bulk of the forests of the central and north-western regions of the sal. In dry types of forest, however, shelter from the south may possibly prove advantageous, though experiments to ascertain this are necessary.

There is still abundant scope for experimental work in ascertaining the best direction for clear strip fellings and for side protection, if required, in different localities and under different conditions. It would simplify working if it were found sufficient to protect the clear strips not on both sides, as in the case of the proposed system of alternate strips, but on one side only, for then the fellings could be made to progress continuously in one direction, as in the usual strip system, with the object of regenerating a given area in a definite period of time. Some examples may now be quoted of systems of concentrated regeneration actually applied to or proposed for sal forests in different localities.

The Thano forest near Dehra Dun, 4,883 acres in extent, on flat to gently sloping ground, has been under concentrated regeneration since 1903, and the prescriptions were completely revised in 1911.¹ The rotation fixed at present is 144 years, which is estimated to produce trees 6 ft. in girth: the rotation is divided into six regeneration periods of twenty-four years each. The state of the crop, which is more or less homogeneous throughout, has made it possible to adopt compact self-contained periodic blocks. The crop consists of well-stocked sal forest subject to frost on the lower ground, but free from it in the upper parts. Natural reproduction is well established throughout almost the whole area, and the regeneration fellings consist merely in removing the overwood from over the young crop. This is being done in two fellings at intervals of twelve years, the idea being to retain part of the overwood as a protection against frost. The yield is fixed by area, definite annual coupes being allotted. In the first felling the aim is to remove about half the overwood, though this is not rigidly adhered to. The degree of removal varies with the state of the young crop: where the latter is well established it is completely freed, otherwise sufficient seed-bearers or protective cover are

¹ Working Plan for the Thano Forest, R. S. Troup, 1911.



FIG. 56. *Shorea robusta* forest worked under concentrated regeneration fellings, immediately before final removal of overwood ; young even-aged crop well established ; Thano forest, Dehra Dun.



FIG. 57. *Shorea robusta* forest worked under concentrated regeneration fellings, young crop 2 years after final removal of overwood, cleaning just completed. Thano forest, Dehra Dun.

retained until the second felling. Ordinarily the maximum limit of girth of well-grown young trees retained to form part of the future crop in the regeneration fellings is $2\frac{1}{2}$ ft., so that for a time the young crop in places has a somewhat uneven appearance. Cleanings and cutting back operations are carried out in the young crop. It is probable that in future revisions of the working plan the removal of the overwood will be prescribed in one instead of in two fellings, as the overwood left is no protection against frost, while the second felling causes much damage to the young crop. Only where frost damage is severe will it probably be necessary to retain side shelter and fell in strips.

The subsidiary fellings in blocks II to VI are selection and improvement fellings. These blocks are definitely allotted to periods, and the fellings are so carried out as to favour in each block the trees which will ultimately form the final crop. The girth limits of trees to be favoured specially are : block II, 3 ft. 6 in. to 6 ft. 6 in. ; block III, 2 ft. 6 in. to 5 ft. 6 in. ; block IV, 1 ft. 6 in. to 4 ft. 6 in. ; block V, 0 ft. 6 in. to 3 ft. 6 in. ; block VI, 0 to 3 ft. 0 in.

Fig. 56 shows a crop in periodic block I immediately before the final removal of the overwood, with a well-established even-aged young crop on the ground. Fig. 57 shows a regenerated young crop two years after the final removal of the overwood ; a cleaning has just been completed.

Concentrated regeneration fellings have recently been introduced in the *bhabar* forests of the Haldwani forest division of the United Provinces.¹ The rotation adopted is 120 years, corresponding to an average girth of 5 ft. This rotation is divided into six regeneration periods of twenty years each, but regenerative operations are actually spread over a double period of forty years in two stages : (1) twenty years in the preparatory stage, the work consisting of light fellings, extensive soil preparation and cultural operations, and (2) twenty years in the secondary stage, comprising the removal of the overwood and the completion of regeneration. Crops in the latter stage are allotted to period I, and those in the former stage to period II. The allotment of crops to periods has been made according to the condition of the various crops, and the treatment prescribed in each case is as follows :

(a) Period I. Crops in which there is much mature overwood and much natural reproduction : these have passed the preparatory stage and have reached the secondary stage.

(b) Period II. Crops in which there is much mature overwood but very little natural reproduction : these are ready for the preparatory stage, and the operations will consist of preparation of the soil, cleanings, and the burning of the leaf-layer in good seed-years.

(c) Periods III, IV, and V. Middle-aged crops : the treatment will be light improvement fellings and thinnings under a felling cycle of ten years.

(d) Period VI. Crops in which the overwood is very sparse, but in which there is a uniform underwood of poles and saplings, the operation prescribed being the removal of the thin overwood ; no further regeneration will be carried out.

The yield is fixed by volume in periodic block I, and by area in the other periodic blocks. In the former case, however, reasonable elasticity is

¹ Revised Working Plan for the Forests of the Haldwani Division, United Provinces, J. V. Collier, 1914.

permitted, and the utmost freedom is allowed in executing the fellings, which may be made in the form of groups, or uniformly, or otherwise as the conditions of each case may require. In order to ensure that the whole of periodic block I is visited at frequent intervals it is divided into four sub-blocks, and the fellings go round these in a felling cycle of four years.

A concentrated system of working has recently been introduced for some of the sal forests of the Ramnagar division, United Provinces, though the area to which this system is to be applied at present forms only a small proportion of the total area of the division, and contains more or less pure sal forests, often even-aged, occupying flat or gently sloping ground in the outer valleys.¹ Such forests are comprised in the uniform working circle, the area of which is 14,118 acres.

It is proposed for the present to adopt a rotation of 120 years and a regeneration period of 40 years. Woods will be allotted to two groups, as follows :

Group A. Woods to be regenerated during the next 40 years. Actually many of these areas will probably be regenerated completely in half this time, as they contain much regeneration. Normal area = $\frac{1}{3} \times 14,118 = 4,706$ acres : actual area = 3,348 acres.

Group B. Woods not to be regenerated during the next 40 years. Normal area = $\frac{2}{3} \times 14,118 = 9,412$ acres : actual area = 10,770 acres, nearly all consisting of crops estimated to be 1 to 40 years old, with the age-classes in a very abnormal condition.

The order of allotment of the older woods to group A is made theoretically in the following order, the compartments being classified accordingly :

1. Compartments partly regenerated, where fellings must be continued.
2. Those in which the growing stock has deteriorated so much that it is advisable to regenerate them at once.
3. Those containing much over-mature stock in which the trees are deteriorating.
4. Those containing much over-mature stock in which the trees are still healthy.
5. Mature crops.
6. Crops almost mature.

The yield is fixed by area, and silviculture has full play. The following are the more important details regarding groups A and B respectively :

Group A. Regeneration fellings will be undertaken with the object of starting, carrying on, and completing regeneration. The forests of this group are comprised in one felling series, divided into five annual coupes, this number being a submultiple of the period for which the plan is framed : these coupes have been fixed in such a way as to furnish as nearly as possible an equal annual out-turn, for which purpose an enumeration of the older age-classes was carried out. Felling rules are not enunciated in detail, and must vary in different places : all fellings in group A, however, will be carried out for the purpose of regenerating the area, preference always being given to the young crop as opposed to the old one.

¹ Working Plan for the Ramnagar Forest Division, S. H. Howard, 1917.

Group B. This group is divided into ten annual coupes, this number being a submultiple of the period of the plan, and the operations consist of thinnings, including the removal of inferior species and of the overwood remaining over young poles and other stems, an operation which will be particularly necessary during the earlier years of the rotation. A classification of thinnings is given in an appendix to the working plan. Briefly they will be conducted thus : (a) crops whose principal height-growth is not complete, moderate or heavy ordinary thinnings ; (b) crops whose principal height-growth is complete, crown thinnings, at first light but becoming progressively heavier as the age increases. On no account will regeneration fellings be made in group B, the fellings being entirely in the interest of the existing crops, which consist largely of poles.

The period of the plan is twenty years, but it has been recommended that a revision be made after ten years. At each revision the rotation, the allotment of crops, and other matters will be entirely reconsidered according to the condition of the crops at the time, and in the light of further experience : in addition new areas now outside this working circle may possibly be brought into it.

The Gorakhpur forests of the United Provinces are situated on flat ground. Until recently the more accessible blocks have been treated under coppice-with-standards and the remainder under light improvement fellings. Under the latest working plan ¹ a system of high forest with concentrated regeneration fellings has been introduced. The management is simplified by the fact that frost is negligible, while natural reproduction is already present in quantity, particularly in the areas hitherto worked under coppice-with-standards, except in certain areas of comparatively small extent, where it has failed owing to illicit grazing, with the consequent hardening of the soil, want of surface drainage, a dense carpet of leaves at the time the seed falls, and want of light. Experiments have shown that on such areas a young crop can be obtained successfully by opening the canopy, fencing against grazing, hoeing the soil, burning the layer of dead leaves, and sowing sal seed. The planting of strong nursery plants with stem and root pruned down also gives promise.

The treatment prescribed in the areas previously worked as coppice-with-standards consists of nothing more than a clear-felling in the nature of a final felling over a regenerated crop, and the new crop will consist partly of coppice and partly of seedling growth. The fellings will be carried out in annual coupes, and will be followed by repeated cleanings in the young crop ; the produce of these cleanings is saleable owing to a keen demand for small material. In places where natural reproduction fails, artificial aid will be resorted to. The rotation adopted tentatively is one of forty years, the aim being to produce fair-sized poles.

In the areas previously worked under light improvement fellings there is often much suppressed reproduction, but the fellings have been too light to produce a vigorous young crop. Here provisional treatment under improvement fellings for the removal of overmature and unsound stems is prescribed for a preparatory period of ten years, during which regenerative measures will

¹ Working Plan for the Forests of the Gorakhpur Division, United Provinces, R. G. Marriott, 1915.

at the same time be commenced in those portions which it is intended to place in periodic block I at the end of this preparatory period, when in all probability the treatment applied will be similar to that now applied to the areas formerly worked under coppice-with-standards. The regenerative measures to be commenced during the preparatory period will be the freeing of advance growth and the stimulation of further reproduction in the manner indicated above. The rotation has not yet been fixed.

The case of the sal forests of the Duars presents problems of a special nature demanding very special treatment. These forests have already been described above (pp. 70-73). They had their origin in burnt savannah tracts, but continuous fire-protection for some decades has entirely altered the character of the undergrowth, which now consists largely of a dense mass of evergreen shrubs, herbaceous plants, and climbers. Not only has sal reproduction been entirely suppressed, but the altered soil conditions, in the shape of bad aeration due to increased moisture, have rendered it impossible for sal seedlings to establish themselves in spite of intensive cleanings. Experimental fellings, burning, cleaning, and artificial sowings in cleared strips through the forest have proved of no avail, and it is evident that until the condition of the soil has been radically altered, it will be impossible to raise young crops of sal. This, it is known from past experiments, can be effected by clear-felling, burning the refuse, cultivating the soil, and raising crops of sal by artificial means. It has therefore been decided to adopt the system of clear-felling followed by artificial reproduction with the aid of field crops. The results of past sal sowings indicate that great success can be attained by artificial reproduction in this way. In the Duars frost is practically unknown, and if sown on prepared ground in the open, sal seedlings do not die back, but grow rapidly from the start. A sal plantation in the Jalpaiguri district formed by sowings with the aid of field crops had a mean girth of nearly $2\frac{1}{2}$ ft. and a mean height of 70 ft. at an age of 18 to 19 years. On the basis of this and other artificially raised crops it is estimated that trees 6 ft. in girth can be produced by sowings in the open in 50 to 60 years as against 100 to 120 years in the case of natural forest, and the financial gain consequent on the shortening of the rotation and the more complete stocking of the area will be very considerable. For the present, however, it has been decided to adopt a rotation of 80 years, partly for the sake of safety and partly because it is not certain that labour will be available for cultivating and stocking the larger area to be regenerated under a shorter rotation. This rotation will be divided into four regeneration periods of 20 years each. Theoretically this formation of periods would be unnecessary if ample labour could be relied on for the clearing and restocking of a definite area annually; this, however, is not the case at present, and a commencement will be made in regenerating as much as can be dealt with annually with the labour available, the area regenerated annually being gradually increased as labour becomes more plentiful, with the object of completing the regeneration of one-fourth of the whole sal-producing area in 20 years. The areas allotted to periodic block I are those containing least sal: the other periodic blocks will be worked under selection and improvement fellings on a felling cycle of 20 years until their turn comes for regeneration. The establishment of numbers of forest villages

for the purpose of carrying out the works of reproduction and tending will necessitate the creation of many different felling series. So far the work has been purely experimental, and this will probably continue to be the case for some time to come. Some of the results already obtained have been described above (p. 109). A special feature of this system of artificial restocking of clear-felled areas in the Duars is that in order to obtain labour to carry out the temporary cultivation required in connexion with the raising of sal crops, it is necessary to provide the villagers with a certain area of wet cultivation, to the extent, at present, of a maximum of .3 acres per house. This reduces the forest area available, but in spite of this the actual quantity of sal produced per acre over the whole area will be very much larger than it has been in the past, owing to the more complete stocking of the sal crops.

The treatment just described will be applied for the present only to the low-level moist sal forests of the Duars. Want of labour prevents its immediate extension to the waterless high-level tracts which are characterized by a dense undergrowth of *sau* grass (*Pollinia ciliata*), and here annual burning will be carried out in the hope of replacing it by savannah grasses in which sal has more chance of regenerating naturally. If sufficient labour becomes available in future, however, it is not improbable that the system of clear-felling with artificial reproduction may be adopted ultimately.

4. *Tending operations in high forest crops.* The first operations necessary in the treatment of young sal crops are cleanings, which consist in freeing the young sal from weeds, from faster-growing inferior species, and from climbers. As a rule the first cleaning is carried out the year after the main felling, and at the same time damaged or misshapen sal saplings are cut back to near ground-level with the object of causing them to produce straight coppice-shoots: this cutting back operation is of great importance. Recently in the United Provinces experimental cleanings have been carried out two years before the main felling, the object being to prevent coppice regrowth of fast-growing inferior species owing to the shade of the canopy. These experiments have proved highly successful, and it is proposed to extend considerably the system of carrying out cleanings two years before the fellings. In this case the cutting back of badly shaped and damaged sal saplings will still be necessary after the fellings. Cleanings are repeated as long as and at such intervals as may be found necessary.

Thinnings constitute an important operation in the tending of sal crops, although opinions differ as to the intensity with which they should be carried out. That girth increment is stimulated by thinning requires no demonstration. The precise effect on the volume increment per acre of thinnings carried out to different degrees of intensity is under study in numerous sample plots, but these have not yet been under observation long enough to produce detailed results. But in any case such figures must often be of merely academic interest, since thinnings in sal crops should naturally be carried out under the ordinary rules of silviculture, and in this respect the sal does not differ materially from other gregarious species which tend to form dense crops. Generally speaking, it is not held to be advisable to thin sal crops too heavily until the time arrives for opening the canopy for regeneration. It is often necessary, however, to thin existing crops more heavily than would otherwise be advisable in order

to remove inferior species and damaged or otherwise undesirable sal stems interfering with more promising stems. Where cleanings have been carried out properly in young crops, and light thinnings have been commenced early, there should ordinarily be no cause for thinning too heavily at a later stage : under systems of concentrated regeneration matters will be much simpler in this respect than is the case with the majority of the sal crops now existing.

RATE OF GROWTH AND OUT-TURN. 1. *High forest.* The rate of growth of the sal cannot be ascertained with any degree of accuracy by counting rings on stumps, as the rings are not as a rule clearly distinguishable. Numerous sample plots have been under measurement for some years in a number of forest divisions ; in every case the object of these divisional sample plots has been to ascertain the girth increment. In 1910-11 a beginning was made by the Forest Research Institute, Dehra Dun, in the establishment of sample plots in even-aged more or less fully stocked sal crops in different parts of the country, and a large number of these plots, which are remeasured quinquennially, have been established in various types of forest. These Research Institute plots have for their object the determination, among other matters, of girth, height, and volume increment, and of the yields obtained from periodic thinnings. So far these plots have not been in existence long enough to furnish results of a reliable nature, though in course of time the statistics yielded by them should prove fairly comprehensive. Some of the results of measurements made hitherto in these plots are given on pp. 124-127, but as these are based on measurements extending over five years only, they may be accepted as nothing more than provisional.

(a) *Girth increment.* The table on pp. 124-127 gives a series of girth increment figures, based chiefly on the results of measurements in divisional and Research Institute sample plots. As most of the plots in question have not been thinned, and in the case of the divisional plots in particular vary much in density, the figures do not form a good basis for comparative purposes : they are, however, the best obtainable at present. Most of these figures have already appeared in the published statistics issued by the Silviculturist at the Forest Research Institute, Dehra Dun.¹ With the exception of the plantation figures for Buxa and Jalpaiguri in Bengal, all these statistics refer to natural crops. In the case of the plantations the exact age is known. In the case of the natural crops nothing has been added for the time required for a seedling to establish itself ; strictly speaking, therefore, a considerable number of years should be added to the estimated ages as shown.

It should be noted that the figures in the table in question show the estimated rate of growth under past conditions, that is, the crops have in the great majority of cases not been thinned or tended in any way. Properly tended crops would no doubt show a faster rate of growth. Another point to note is that in uneven-aged crops the rate of growth has been calculated not only from the larger and dominant stems, but also from the smaller or dominated stems, all the measurements for one plot being combined ; even though badly suppressed stems have been left out of account, figures so compiled do not correctly represent the rate of growth of a dominant even-

¹ Ind. For. Records, vol. vi, pt. ii, 1917 ; and pt. v, 1918.

aged crop such as correct silviculture should aim at. Most of the divisional sample plots contain trees of widely different girths, and many of the smaller stems on which the rate of growth is estimated must have been suppressed for years. The Research Institute plots are laid out in even-aged crops, and the error in the case of these is probably not so great, but none of these plots have yet been tended regularly for a sufficient length of time to produce the best stem development.

The excessively slow growth in the natural crops of Mandla and Balaghat in the Central Provinces may be contrasted with the rapid growth in the plantations of Buxa and Jalpaiguri in Bengal. That trees artificially raised and tended are capable of rapid growth may be seen from the following measurements made by Dr. Brandis in 1863 in respect of trees of known age at Saharanpur and Calcutta : ¹

Saharanpur, age 13 years, girth 27 in. (mean of 33 trees)	
" " 30 " " 54½ in.	
" " 35 " " 79½ in.	
Calcutta, " 25 " " 69 in.	

The rapid growth of artificially raised sal in the Bengal Duars is shown in the case of a small plot in an abandoned nursery bed at Mendabari in the Buxa district. Seed was sown in June 1911, and the resulting seedlings grew rapidly, without dying back, into a dense clump of saplings. In January 1915 these were thinned out, 43 saplings being left. The following measurements have been recorded for this plot :

Shorea robusta : measurements of artificially raised saplings, Mendabari, Buxa.

Date.	Ago.	Girth.		Height.		Remarks.
	years.	Mean. in.	Maximum. in.	Mean. ft.	Maximum. ft.	
January 1915	3½	5.5	8.4	14	16	43 stems after thinning.
December 1916	5½	9.5	13.5	19.5	25	Excluding 7 suppressed stems.

This plot is shown in Fig. 41.

In 1918 Mr. Marsden formed the following estimate, based on the results of measurements in 61 sample plots in even-aged crops, of the girth increment of sal in the United Provinces, arranged in two tentative quality classes :

Shorea robusta : girth increment in even-aged high forest crops,
United Provinces.

Girth.	Corresponding age.	
ft.	I quality. years.	II quality. years.
1	29	37
2	42	56
3	56	77
4	72	105
5	92	—

¹ For. Flora, p. 27.

IX. DIPTEROCARPACEAE

Shorea robusta : rate of growth in girth, deduced

Province.	Forest division.	Approximate rainfall. inches.	Particulars.	
United Provinces.	Dehra Dun	80-85	Divisional plots.	Fastest growth, unthinned, Malhan range, foot of Siwaliks. Slowest growth, unthinned, Malhan range, near Jhajra Mean of 7 unthinned plots throughout the Dun.
	Saharanpur	50	Divisional plots.	Fastest growth, unthinned, Dholkhand, No. 1. Slowest growth, unthinned, Lakarkot, No. 2. Mean of 7 unthinned plots.
			Research Institute plot in dry hill type, unthinned, reaching small dimension only.	
	Haldwani	70-80	Research Institute plots.	No. 6. Fastest growth, unthinned. Sal forest of very good quality. No. 1. Slowest growth, unthinned. Pure uniform pole crop, fully stocked; plateau foot of hills; soil sandy loam with small boulders. Mean of 7 unthinned plots.
	Pilibhit	50-55	Divisional plots.	Fastest growth, unthinned, Banbasa compartment V. Slowest growth, unthinned, Neoria compartment XV. Mean of 9 unthinned plots. Mean of 2 thinned plots.
			Research Institute plot. Forest of somewhat poor quality, unthinned density 0.8.	
	North Kheri	50	Divisional plots.	Fastest growth, unthinned, high-level forest, West sal working circle compartment 9 b. Slowest growth, unthinned, <i>phantia</i>-belt type, of good height-growth, West sal working circle compartment 30. Mean of 5 unthinned plots.
			Research Institute plots.	No. 7. Fastest growth, unthinned, high-level forest of good quality. [Note. Some plots showed fast growth, but figures available up to 60 years only.] No. 5. Slowest growth, unthinned, low-level <i>phantia</i> belt type of good quality. Mean of 10 unthinned plots.
	South Kheri	45	Divisional plots.	Fastest growth, unthinned, Gola working circle coupe VIII. Slowest growth, unthinned, Kishenpur working circle coupe VI. Mean of 8 unthinned plots.
	Bahraich	42-45	Divisional plots. Research Institute plots similar in all.	Fastest growth, unthinned, Murtiha II. Slowest growth, unthinned, No. 1, Nishangara I. Mean of 9 unthinned plots. plots, mean of 5 unthinned plots, growth somewhat
	Gonda	55-60	Research Institute plots.	Thinned. Fastest growth, plot No. 6, forest of very good quality, heavily thinned. Slowest growth, plot No. 8, forest of very good quality, moderately thinned. Mean of 3 thinned plots. Unthinned. Fastest growth, plot No. 5, forest of very good quality, adjoining No. 6, above Slowest growth, plot No. 7, forest of very good quality, adjoining No. 8, above Mean of 3 unthinned plots.

from measurements in high forest sample plots.

No. of measure- ments.	Age in years.													
	20	40	60	80	100	120	140	160	180	200	220	240	260	
	Corresponding girth at breast height.													
	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	
100	1 0	1 9½	2 7	3 5	4 3	5 1	5 11½	..	..	..	..	..	..	
248	..	0 7½	1 1	1 7	2 1	2 6½	3 0½	3 7½	4 3½	5 1½	5 11½	..	..	
1680	0 8	1 4	1 11	2 6	3 2	3 10	4 7	5 4	6 0	6 9	..	..	..	
149	..	0 8½	1 2½	1 9½	2 4½	3 0	3 8	..	..	..	..	..	..	
18	..	0 4½	0 7½	0 11	1 2½	1 5½	1 9	2 0½	2 4	2 9	..	..	..	
860	..	0 6½	0 10½	1 2½	1 6½	2 0	2 6	3 0	3 7	4 3	5 1	6 0	..	
96	0 4	0 9½	1 3	1 7½	..	..	..	..	..	..	..	..	..	
53	0 4½	1 0	1 7½	2 2½	2 10½	3 8	4 8	5 10½	..	..	..	..	..	
152	0 4	0 8	1 0½	1 4½	1 8½	2 1	2 6½	3 0½	3 7½	4 3½	5 0	5 8½	..	
615	0 4½	0 11½	1 6½	2 2	2 9½	3 6½	4 3½	5 0½	5 9½	6 6½	..	..	..	
38	0 7	1 9½	2 11	3 11½	4 11	..	..	..	..	..	..	..	..	
63	0 4	0 11½	1 6½	2 1	2 7	3 1½	3 7½	4 2½	4 9½	5 3½	..	..	..	
884	0 7	1 7	2 6	3 4½	4 2½	4 11½	5 8	..	..	..	..	..	..	
76	0 8½	1 8½	2 8	3 8½	4 8½	5 10	..	..	..	..	..	..	..	
154	0 8½	1 3½	1 11½	2 8½	3 8½	..	..	..	..	..	..	..	..	
64	..	1 11½	3 2	4 3½	5 7	..	..	..	..	..	..	..	..	
64	..	1 2	1 10½	2 6	3 1½	3 9½	4 5	5 0½	5 8	6 3½	6 11	..	..	
290	..	1 5½	2 4½	3 3	4 1	4 11	5 9	6 7	..	..	..	..	..	
29	0 9½	1 9½	2 10½	3 11½	..	..	..	..	..	..	..	..	..	
69	0 5	0 10½	1 4½	1 11½	2 5½	3 0½	3 7½	4 1½	4 7½	..	..	..	..	
370	0 10	2 0	2 11½	3 9½	4 7½	..	..	..	..	..	..	..	..	
29	..	1 5½	2 7½	3 10	4 8½	..	..	..	..	..	..	..	..	
81	..	0 6	1 0	1 4	1 8½	2 1½	2 6½	2 11½	3 5	3 10	4 3	4 8	5 0½	
394	..	1 1½	1 11½	2 9½	3 7	4 4½	5 1	5 9	..	..	..	..	..	
55	1 0½	2 3½	3 7½	4 10½	..	..	..	..	..	..	..	..	..	
63	0 5½	0 11½	1 6½	2 2½	3 1½	4 1½	5 4½	..	..	..	..	..	..	
692	0 8	1 6	2 4	3 3	4 2	5 0	..	..	..	..	..	..	..	
152	0 9½	1 8½	2 7½	3 6½	4 5½	5 4½	..	..	..	..	..	..	..	
67	..	1 6	2 8½	4 0½	5 6½	..	..	..	..	..	..	..	..	
90	..	0 6½	1 0½	1 7	2 3	3 1½	4 1½	5 1½	..	..	..	..	..	
408	..	0 5½	1 0½	1 8	2 4½	3 4	4 5½	5 8½	..	..	..	..	..	
68	..	0 7	1 2	1 9½	2 6	3 4½	4 4½	5 6½	..	..	..	..	..	
97	..	0 4½	0 8½	1 1½	1 6½	2 0	2 7½	3 4½	4 3½	5 1	5 10½	..	..	
546	..	0 4½	0 8½	1 2½	1 8½	2 2½	2 10½	3 8	4 7½	5 7½	..	..	..	

Shorea robusta : rate of growth in girth, deduced

Province.	Forest division.	Approximate rainfall, inches.	Particulars.	
Bengal.	Darjeeling (Tista valley range)	175	Divisional plots.	{ Fastest growth, unthinned, Riang. Slowest growth, unthinned, Riang. Mean of 5 unthinned plots.
	Jalpaiguri	150	Divisional plots.	Mean of 4 unthinned plots in Lower Tendu and Muraghat Forest of good quality.
	Buxa	160	Divisional plots.	Mean of 8 unthinned plots, 4 in dry (high-level), 4 in moist (low-level) forest; rate of growth almost identical in both types.
	Buxa and Jalpaiguri	..	Plantations.	{ Good quality. Fair quality.
Assam.	Goalpara	155	Divisional plots.	Mean of 2 unthinned plots in high-level forest.
	Darrang	90	Divisional plots.	Mean of 2 unthinned plots in Gorumara and Balipara growth nearly same in both.
Bihar and Orissa.	Singhbhum and Kolhan	55-65	Divisional plots.	{ Mean of 4 unthinned plots, valley type. Mean of 4 unthinned plots, hill type.
	Palamau	50	Divisional plots.	Mean of 3 unthinned plots, Kari and Kusumbhar.
	Puri	55-60	Divisional plots.	Mean of 2 unthinned plots, Kaduapara and Rajin.
	Angul	50-55	Divisional plots.	{ Fastest growth, unthinned, Nimbochali. Slowest growth, unthinned, Rosonda. Mean of 5 unthinned plots.
	Santal Parganas	50-60	Divisional plots.	{ Fastest growth, Kotangi, ferruginous lateritic soil. Slowest growth, Majdiha, ferruginous lateritic soil. Mean of 10 plots, all unthinned except two.
Central Provinces.	South Mandla	55	Divisional plots.	{ Fastest growth Pakwar, very open forest, fair quality. Slowest growth, Kikra, somewhat open crop, poor quality lateritic soil near trap. Mean of 6 unthinned plots.
	Balaghat	60	Divisional plots.	{ Fastest growth, No. 7a, Topla, moist, free from frost. Slowest growth, No. 2, Barkhera, much damaged by frost. Mean of 23 unthinned plots.

from measurements in high forest sample plots.

No. of measure- ments.	Age in years.													
	20	40	60	80	100	120	140	160	180	200	220	240	260	
	Corresponding girth at breast height.													
	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	
63	0 9½	1 8½	2 7½	3 9½	5 0	6 1	..	..	..	..	..	..	..	
29	0 7½	1 4½	2 3	3 3½	4 3	5 0½	5 9½	6 8½	..	..	..	..	..	
156	0 9½	1 9	2 11½	4 0½	4 11½	5 8	6 4½	7 1½	7 11½	..	..	..	..	
262	0 11	1 11	3 1	4 5	6 0	7 7	..	..	..	..	..	..	..	
289	1 0	2 0	3 0	4 0	5 0	6 0	..	..	..	..	..	..	..	
..	2 6	5 0*	6 3*	at 50 years of age]				..	..	..	..	..	..	
..	2 0	4 0	6 0*	..	..	..	..	..	..	..	..	..	..	
105	0 8	1 6	2 6	3 6	4 6	5 6	..	..	..	..	..	..	..	
380	0 4	0 10½	1 5½	2 1	2 9½	3 7	4 5½	5 5½	..	..	..	..	..	
132	0 8	1 5½	2 3½	3 2	4 0	4 10	5 8½	6 6½	7 4½	..	..	..	..	
163	0 10	1 8½	2 7	3 4	4 0½	4 8½	5 5	6 1½	6 10	..	..	..	..	
91	0 10½	2 0	3 3½	5 0	..	..	..	..	..	..	..	..	..	
133	0 10	1 9½	2 11½	4 2½	5 6½	..	..	..	..	..	..	..	..	
39	..	1 9	2 10	4 0½	5 2½	6 5½	..	..	..	..	..	..	..	
71	..	1 4½	2 1½	2 10½	3 8½	4 7½	5 6½	6 6½	7 5½	..	..	..	..	
197	..	1 7½	2 6½	3 7½	4 10	6 0	7 0	7 11	..	..	..	..	..	
46	1 2	2 4½	3 5½	4 7	..	..	..	..	..	..	..	..	..	
44	0 5½	1 0	1 6½	2 0½	2 7½	3 1½	3 8	..	..	..	..	..	..	
609	1 4½	2 4½	3 2½	4 0½	4 10½	..	..	..	..	..	..	..	..	
41	..	1 1	1 10	2 7½	3 4½	4 2½	5 0	5 9½	6 6	6 11½	7 4½	7 9½	..	
72	..	0 7	0 11½	1 4	1 8	2 0	2 3½	2 7½	2 11½	3 3½	3 7½	4 0	4 3½	
795	..	0 8½	1 2½	1 7½	2 0½	2 5½	2 11	3 4	3 9	4 2½	4 7½	5 1	5 6½	
(Girth of 6 ft. attained in 284 years.)														
18	..	0 8½	1 3	1 9½	2 4½	3 1	3 11	4 9½	..	..	..	..	..	
33	..	0 1½	0 4	0 7	0 10	1 0½	1 3½	1 6½	1 9	2 0	2 3½	2 6½	2 10	
1815	..	..	0 6½	0 9½	1 1	1 5½	1 9	2 1	2 5½	2 10½	3 3½	3 8	4 1	
(Girth of 6 ft. attained in 365 years.)														

* Estimated on basis of rate of growth for younger ages.

(b) *Form factors.* The following table of form factors, for all qualities combined, has been compiled from numerous measurements of typical trees in even-aged sample plots laid out by the Forest Research Institute :

Shorea robusta : form factors.

Form factor.			Form factor.		
Height of tree. ft.	Timber.	Total timber and small-wood.	Height of tree ft.	Timber.	Total timber and small-wood.
11-20	—	0.47	61-70	0.20	0.42
21-30	—	0.48	71-80	0.24	0.41
31-40	—	0.49	81-90	0.28	0.40
41-50	—	0.48	91-100	0.30	0.39
51-60	0.16	0.45	101-110	0.31	0.38

Note. (1) Form factor = $\frac{v}{sh}$, where v = solid volume in cubic feet, s = sectional area at breast-height, h = total height of tree.

(2) Timber excludes bark, and comprises everything down to a girth of 24 in. measured over bark ; small-wood includes bark, and comprises material 6 in. to 24 in. in girth.

Mr. J. V. Collier prepared the following statement of form factors of marketable timber in the bole, based on measurements of tall straight trees growing in the best quality of locality in the Haldwani forests : ¹

Girth	4 ft.	4½ ft.	5 ft.	5½ ft.	6 ft.
Timber form factor	0.60	0.59	0.56	0.57	0.56
Waste per cent. in conversion to scantlings	19	20	19	20	19

(c) *Volume measurements.* Although numerous volume measurements of whole woods have been made in Research Institute sample plots, the compilation of results cannot be usefully attempted until further periodical remeasurements have been carried out, after which it should be possible to ascertain the rate of growth with some degree of accuracy, to define quality classes, and to make an estimate of intermediate yields. Current measurements in such crops have been published from time to time in the *Indian Forest Records*, but a compilation of general results has not yet been attempted.

Numerous figures giving the out-turn of coupes or the average out-turn of single trees are on record in different localities. These are of use locally, but for general comparative purposes they are for the most part of little value, since the out-turns have resulted mainly from very abnormal crops worked under selection or improvement fellings carried out under varying conditions, and in many cases the trees felled have been largely unsound or misshapen.

The following measurements made in 1916 and 1917 in sal plantations at Bareilly and Gorakhpur, on alluvial ground on the plains of northern India, are of interest :

Shorea robusta : measurements in plantations, Bareilly and Gorakhpur, United Provinces.

		Volume per acre.						
Locality.	Age. years.	Number of stems per acre.	Mean		Timber 24 in. in girth and over.	Small- wood un- der 24 in. in girth.	Mean annual volume increment	
			girth.	height.			Total.	per acre.
			ft.	in.	ft.	cub. ft.	cub. ft.	cub. ft.
Bareilly	59	100	4	9	85	3,688	977	4,665
Gorakhpur	30	295	2	4	65	926	1,480	2,406
								79.07
								80.2

¹ Working Plan for the Haldwani Forest Division, United Provinces, 1914.

As regards the out-turn of single trees, two examples may be quoted in which the measurements were carefully made in respect of selected typical trees.

Mr. J. V. Collier in 1913-14 made some measurements of the out-turn of sal timber and scantlings from sound dominant trees in uniform close crops in the best quality of locality in the *bhabar* tract of the Haldwani forest division, United Provinces. The following statement gives a summary of the results :

Shorea robusta : average measurements and out-turn from well-grown sound dominant trees, Haldwani.

No. of trees measured.	Girth at 4½ ft. ft.	Estimated age. years.	Total height of tree. ft.	Length of timber bole. ft.	Middle girth of timber bole		Volume of timber bole without bark (πr^2). cub. ft.	Out-turn of scantlings. cub. ft.
					over bark. ft. in.	under bark. ft. in.		
48	6	134	99	59	4 5	4 0	75.7	46
49	5½	121	99	60	4 2	3 8	64.7	38.4
49	5	109	98	60	3 9	3 4	54.8	32.8
50	4½	97	95	56	3 5	3 1	41.8	23.3
50	4	86	93	55	3 1	2 9	33.9	17.9

The following are the results of measurements made by Mr. A. K. Glasson of a number of typical trees of different sizes in forest of good quality in Jalpaiguri, Bengal :

Shorea robusta : out-turn of typical trees, Jalpaiguri.

Girth. ft.	Average volume in the round. cub. ft.	Girth. ft.	Average volume in the round. cub. ft.
3	16	5	54
3½	23	5½	68
4	32	6	81
4½	42	over 6	90

As an example of a large out-turn from a single tree the case may be quoted of a tree felled in 1915 in the Tholkobad block, Singhbhum, which had a girth of 11 ft. 4 in. and a bole 60 ft. long. The out-turn of sleepers was as follows :

53 broad-gauge measuring	79.5 cub. ft.
34 metre-gauge measuring	39.4 „
14 narrow-gauge measuring	15.4 „
Total	134.3 „

(d) *Bark allowance.* Numerous measurements of bark thickness in the Dehra Dun forests gave the following averages :

Girth . . .	1-2 ft.	2-3 ft.	3-4 ft.	4-5 ft.	5-6 ft.
Bark thickness .	0.7 in.	0.9 in.	0.9 in.	1.1 in.	1.1 in.

Mr. J. V. Collier found the average percentage of bark in the total volume of the bole in the case of well-grown trees 4 to 6 ft. in girth in the Haldwani forests to be about 20.

2. *Coppice*. The height-growth of sal coppice is comparatively fast for the first two or three years, after which it becomes slower. Certain companion species—for example, *Grewia vestita*, *Lagerstroemia parviflora*, *Kydia calycina*, *Careya arborea*, *Cassia Fistula*, and *Terminalia tomentosa*—usually outgrow the sal in the earlier stages, but before long the latter overtakes all these species except *Terminalia tomentosa*, which keeps more or less level with it.

The following statement gives the results of measurements made in coppice coupes in different localities :

Shorea robusta : rate of growth of coppice.

Ramgarh, Gorakhpur dist., U.P. Plains type. Age. (C. M. McCrie, 1910.)			W. Lehra, Gorakhpur dist., U.P. Plains type. (Author, 1911.)			Dolmar, Naini Tal dist., outer Hima- laya; hilly ground. (E. A. Smythies.)			Saitba, Kolhan forest division, Bihar and Orissa ; poor hilly ground. (Author, 1916.)			Kulkaut sample plot, Santal Parganas.
Mean girth.		Mean height.	Mean girth.		Mean height.	Mean girth.		Mean height.	Mean girth.		Mean height.	Mean height.
years.	ft.	in.	ft.	in.	ft.	ft.	in.	ft.	ft.	in.	ft.	
2	..		3	0 2.6	6	0	5	13	0	4	9	..
4	0 2		7	0 4.4	11	0	8.6	21	0	6.5	16	..
6	0 2.9		10.3	0 5.4	14	1	0	26	0	8.6	20	..
8	0 3.8		13	0 6.4	17	1	1.7	30	0	10.3	22.5	..
10	0 4.8		15.3	0 7.2	20	1	3.2	34	0	11.5	24.5	27
12	0 5.8		17.5	0 8	22.5	1	4.4	38	1	0.6	26.5	..
14	0 6.7		19.2	0 8.8	25	1	5.6	42	1	1.6	28.5	..
16	0 7.5		20.9	0 9.6	27	1	6.8	45	1	2.5	30	..
18	..	..	..	..	..	1	8	48	..	..	..	..
20	..	..	..	..	..	1	9.2	..	..	..	..	43
30	..	..	..	..	..	..	..	..	..	..	..	56

Out-turn figures for coppice recorded in coupe registers are not always to be relied on, since the figures are often vitiated by the inclusion of the out-turn of standards. The statement on the next page, compiled from measurements made by me in 1911 in coppice coupes in the West Lehra and Ramgarh forests, Gorakhpur, United Provinces, gives an idea of the volume yielded by coppice in coupes of different ages, (a) in specially selected fully stocked plots, and (b) as a general average. The measurements were made along straight lines $\frac{1}{4}$ chain wide running through the coupes and embracing crops of various degrees of stocking.

2. *Shorea Tumbuggaia*, Roxb. Syn. *Vatica Tumbuggaia*, W. and A. Vern. *Karunthumbi*, *tambagai*, Tam. ; *Thamba*, Tel.

A large tree with dark, thick, rough, longitudinally fissured bark. Trees up to 6 or 7 ft. in girth and 50 or 60 ft. in height are met with occasionally, but most of the large trees have been cut out : old stumps show that at one time trees up to 20 ft. in girth were sometimes to be found. This species does not attain so great a height as *S. Talura*. Wood very hard and durable, used for house-building, particularly for posts, rafters, and door and window frames. It lasts well under water, and is much used for well-linings.

DISTRIBUTION AND HABITAT. The tree occurs most plentifully, although its distribution is somewhat limited, in the Seshachellam and Veligonda hills in the Cuddapah and North Arcot districts of Madras : it is also found in limited quantity in the Kambakkan and Nagalapuram hills of the Chingleput

SHOREA

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Shorea robusta : coppice measurements, Gorakhpur, United Provinces.

Locality.	Age. years.	Density: (a) Fully stocked patches ; (b) General average.	Number of stems per acre (4 in. girth and over).			Mean girth (sal 4 in. girth and over).	Mean height (sal 4 in. girth and over).	Solid volume per acre (material 6 in girth and over).			Mean annual volume increment per acre (all species).
			Sal.	Other species.	Total.			Sal. cub. ft.	Other species, cub. ft.	Total. cub. ft.	
W. Lehra coupe 10	8	{	1,690	262	1,952	..	..	235	23	258	32
		{ (b)	574	429	1,003	6.5	17	100	33	133	17
W. Lehra coupe 6	12	{	1,000	560	1,560	..	..	330	84	414	34
		{ (b)	561	809	1,370	8.2	23	185	121	306	25
Ramgarh coupe 6	12	{	1,480	1,880	3,360	..	..	283	139	422	35
		{ (b)	850	1,038	1,888	7.0	20	162	77	239	20
W. Lehra coupe 5	13	{	1,103	1,426	2,529	..	..	386	271	657	55
		{ (b)	476	916	1,392	8.5	22	167	174	341	26
W. Lehra coupe 4	14	{	901	1,868	2,769	..	..	261	299	560	40
		{ (b)	492	1,051	1,543	8.2	23	143	168	311	22
W. Lehra coupe 3	15	{	818	536	1,354	..	..	406	149	555	37
		{ (b)	681	580	1,261	9.4	27	338	161	499	33
Ramgarh coupe 3	15	{	1,545	1,600	3,145	..	..	295	152	447	30
		{ (b)	910	912	1,822	7.2	23	174	87	261	17

district. It is found chiefly in hilly country on well-drained ground, associated with *Pterocarpus santalinus*, *P. Marsupium*, *Anogeissus latifolia*, *Chloroxylon Swietenia*, *Terminalia tomentosa*, *T. Chebula*, *Buchanania latifolia*, *Eugenia Jambolana*, *E. alternifolia*, *Diospyros Melanoxylon*, *Dalbergia latifolia*, and other species, often with an undergrowth of *Phoenix humilis*. The tree is to some extent gregarious, forming patches of varying extent, chiefly on the upper slopes and crests of the hills and on plateaux, on well-drained ground with a soil usually consisting of red loam and gravelly sand. Fig. 58 shows a typical patch of forest. On dry ridges and plateaux the tree tends to become stunted, but on lower slopes and in valleys it reaches good dimensions. In its natural habitat the absolute maximum shade temperature is about 110° F., and the absolute minimum about 55° F.: the rainfall is about 30–35 in., of which more than half falls during the south-west monsoon from May to September, the greater portion of the remainder falling during the north-east monsoon from October to December.

FLOWERING AND FRUITING. The flowers appear in March–April, and the fruits ripen in June–July. Good seed-years are said to occur about once every two years. The seed occasionally starts germinating before falling from the tree; like that of other dipterocarps, it loses its fertility quickly, and if timely rain does not occur at the time the fruit falls or immediately after the seed fails to germinate.

SILVICULTURAL CHARACTERS. *Shorea Tumbuggaia* belongs to the xerophilous type of dipterocarps (see p. 32). Its silvicultural characters have not been studied in detail, but it apparently has good power of recovery from injury, having survived the effects of continued burning in the dry hilly tracts in which it is found. Natural reproduction in the Seshachellams is reported to be good in fire-protected areas.

3. *Shorea obtusa*, Wall. Vern. *Thitya*, Burm.

A large deciduous usually gregarious tree reaching a height of 80 ft. or more and a girth of 10 ft. and over; Mr. A. Rodger records one of 17 ft. in the Ruby Mines district. Bark thick, dark grey, brown inside, rough with deep longitudinal fissures. Wood very hard and durable, much used for building. Lac is occasionally produced on this tree.

DISTRIBUTION AND HABITAT. Except that it does not extend so far north, the distribution and habitat of this tree and its climatic requirements are practically the same as those of *Pentacme suavis*, with which it is very commonly associated in similar types of forest. It occurs as far north as the Ruby Mines district between 23° and 24° N. lat., and it is mentioned in the list of trees occurring in the Mawku and Ahlaw working circles in the Upper Chindwin district, 23° to 24° N. lat. (working plans by L. C. Davis and S. F. Hopwood).

LEAF-SHEDDING, FLOWERING, AND FRUITING. The leaves are shed in the early part of the hot season; the tree remains leafless during a portion of that season, or in moister localities the new leaves may appear very soon after the fall of the old ones. The inflorescences of yellowish fragrant flowers appear in March and the fruits ripen in May. The latter are five-winged, three of the wings being about 2 in. and the other two about 1½ in. long. The fruits are light and are blown to considerable distances: like that of



FIG. 58. *Shorea Tumbuggaia* at 2,500 ft. elevation on the Seshachellam hills, South Cuddapah, Madras, with undergrowth of *Phoenix humilis*.



FIG. 59. *Shorea Talura* in Pikkilikona valley, Seshachellam hills,
South Cuddapah, Madras.

other dipterocarps, the seed germinates soon after falling, and will not keep any time.

SILVICULTURAL CHARACTERS. *Shorea obtusa* belongs to the xerophilous type of dipterocarps (see p. 32), and its silvicultural characters are practically the same as those of *Pentacme suavis*. As in that species, the growing period is short, being confined to the hot season. The tree coppices well up to a moderate size, but is not known to produce root-suckers.

NATURAL REPRODUCTION. As with *Pentacme suavis*, reproduction is usually good, but the conditions governing it have not yet been studied in detail.

4. *Shorea Talura*, Roxb. Syn. *S. laccifera*, Heyne; *Vatica laccifera*, W. and A. Vern. *Talura*, *talari*, *punna-marom*, Tam.; *Jalari*, Tel.; *Jala*, Coorg; *Jhallanda*, Mysore; *Jhall mara*, Kan.

A large tree attaining a height of 80 ft. and a girth of 8-10 ft. Bark grey, somewhat smooth. Wood moderately hard, much used for house-building and for the large front posts of temples. Lac is sometimes produced on the tree.

DISTRIBUTION AND HABITAT. The southern Deccan districts of Madras, in Cuddapah, North Arcot and Anantapur, Mysore, Coorg, the Wynaad, Malabar, Coimbatore, and Madura, up to 3,000 ft. elevation. Travancore in Morrayur and Anjanad, rare (Rama Rao). This is a tree of the moist or evergreen forests in damp ravines and valleys, sides of streams, and lower slopes of hills, where it is associated with *Mangifera indica*, *Mimusops Elengi*, *M. hexandra*, *Eugenia Jambolana*, *Morinda tinctoria*, *Pterocarpus Marsupium*, *Dalbergia latifolia*, *Terminulia* spp., and other trees, and sometimes with *Shorea Tumbuggaia* and *Pterocarpus santalinus* in the southern Deccan hills. It is hardly a gregarious species, though it often occurs in patches of varying extent. Fig. 59 shows the type of forest in which it occurs. In its natural habitat the rainfall varies from 30 to 80 in. and possibly more, most of the rain falling between May and September and the greater portion of the rest from October to December: the absolute maximum shade temperature is about 110° F., and the absolute minimum about 50° F.

FLOWERING AND FRUITING. The white or pale pink flowers appear in February-March, and the fruits ripen in April-May.

SILVICULTURAL CHARACTERS. The silvicultural characters of this tree have not been studied in detail, but judging from its habitat it probably belongs to the hygrophilous type of dipterocarps (see p. 32). It is said to regenerate freely.

5. *Shorea assamica*, Dyer. Vern. *Makai*, Assam.

A very large tree with a long clean bole and rough brown bark. Wood light brown, handsome, open grained, much softer than that of *Shorea robusta*; it is of good quality, and if more plentiful would undoubtedly be in demand for various purposes.

DISTRIBUTION AND HABITAT. Upper Assam at the foot of the Naga hills in the Sibsagar and Lakhimpur districts in evergreen forests. Upper Burma in the Katha district, in moist valleys. Mr. Milroy¹ says it is reported to occur in evergreen forest in the Abor country near Pobamukh, associated

¹ Report on the Resources of the Abor Country, 1912.

with *Cedrela Toona*, *Terminalia myriocarpa*, *Castanopsis tribuloides*, *Amoora Wallichii*, *Cinnamomum Cecicodaphne*, *Morus laevigata*, *Michelia Champaca*, *Gmelina arborea*, and other species. In Assam it occurs sporadically mixed with many other kinds of large trees, or occasionally it is found growing more or less gregariously in patches of varying extent.

In its natural habitat the absolute maximum shade temperature is about 100° to 102° F., the absolute minimum about 40° F., and the normal rainfall 80 to 160 in.

LEAF-SHEDDING, FLOWERING, AND FRUITING. Mr. Kanjilal informs me that in Assam the old leaves are shed from March onwards and the new leaves appear during the rains between June and August. It flowers in September, and the fruits ripen in January–February. In its region in Upper Assam there is much rain from February onwards.

SILVICULTURAL CHARACTERS. This species belongs to the hygrophilous type of dipterocarps (see p. 32). Its silviculture has not been studied in detail.

RATE OF GROWTH. Gamble's specimens showed 5 rings per inch of radius, giving a mean annual girth increment of 1.26 in., which is fairly fast.

5. PARASHOREA, Kurz.

Parashorea stellata, Kurz. Vern. *Kaunghmu*, Burm.

A very tall evergreen tree of the tropical forests of Martaban and Tenasserim and the eastern slopes of the Pegu Yoma. The flowers appear in March–April and the five-winged fruits ripen in April–May.

6. BALANOCARPUS, Bedd.

Balanocarpus utilis, Bedd. Black kongu. Vern. *Karin kongu*, Tinnevely.

A large evergreen tree which has already been described to some extent under *Hopea parviflora*, with which it is often associated in that district. It has a smooth bark, which is much darker than that of *Hopea*. It flowers from the end of April to the beginning of June, and the fruit, which is wingless, ripens in the rains, falling under and around the trees, where regeneration springs up in quantity. This tree is more shade-bearing than *Hopea*. *Balanocarpus erosa*, Bedd., which is associated with *B. utilis*, has a larger and heavier wingless fruit.

7. VATERIA, Linn.

Vateria indica, Linn. Piny varnish or Indian copal tree.

A large handsome evergreen tree with a smooth grey bark and a cylindrical stem. Mr. H. Tireman records trees up to 17 ft. 3 in. in girth in the Coorg *ghat* forests. The tree yields a gum-resin of excellent quality. It has been extensively planted as an avenue tree in South Canara, Malabar, and Travancore.

DISTRIBUTION AND HABITAT. Western India from North Kanara to Travancore, up to 3,500 or 4,000 ft., chiefly in evergreen forests, but occasionally along rivers in deciduous forests. In Coorg it occurs both in the *ghat* forests and east of the *ghats* up to 3,500 ft. elevation, in the latter locality always in evergreen forest. Its most important companions are *Hardwickia pinnata*, *Hopea parviflora*, *Dipterocarpus indicus*, *Dysoxylum malabaricum*,

Artocarpus hirsuta, *A. integrifolia*, *Calophyllum tomentosum*, *Dichopsis elliptica*, and *Mesua ferrea*. Enumerations carried out in 1914–15 by Mr. N. E. Shrigley in the evergreen forests of Coorg showed that this was the most plentiful of all the important species, there being on an average 73 trees $7\frac{1}{2}$ ft. and over in girth per 100 acres. In the natural habitat of the tree the climate is humid : the absolute maximum shade temperature varies from 95° to 100° F., the absolute minimum from 55° to 65° F., and the normal rainfall from 80 to 200 in. or more.

FLOWERING AND FRUITING. The flowers appear from January to March, and the fruits ripen from May to July. The fruits are fleshy and wingless, 2–2.5 in. long, containing one large seed.

SILVICULTURAL CHARACTERS. The tree belongs to the hygrophilous type of dipterocarps (see p. 32). It is a pronounced shade-bearer.

NATURAL REPRODUCTION. The heavy seed falls close around the tree ; it germinates readily, and natural reproduction is usually plentiful in the neighbourhood of seed-bearers, the seedlings standing a considerable amount of shade.

ORDER X. MALVACEAE

The trees of this order which are of chief forest importance in India are *Bombax malabaricum*, DC., the cotton tree, with a soft whitish wood used for packing-cases and in match-manufacture ; *B. insigne*, Wall., with a similar but somewhat better wood ; and *Kydia calycina*, Roxb., important more as a common Indian forest tree than as being of any great economic value. The order contains many plants of economic importance as producers of fibres, both from the bast and from the fruits ; to the latter class belong the cotton plants (*Gossypium* spp.).

Genera 1. BOMBAX, Linn. ; 2. KYDIA, Roxb. ; 3. THESPESIA, Correa ; 4. ERIODENDRON, DC. ; 5. ADANSONIA, Linn. ; 6. DURIO, Linn. ; 7. CULLENIA, Wight.

1. BOMBAX, Linn.

Large deciduous trees with digitate glabrous leaves.

Species 1. *B. malabaricum*, DC. ; 2. *B. insigne*, Wall. ; 3. *B. scopulorum*, Dunn.

1. **Bombax malabaricum**, DC. Syn. *B. heptaphyllum*, Cav. Cotton tree. Vern. *Simal*, Hind. ; *Sayar*, Mar. ; *Burla*, *sauri*, Kan. ; *Burgha*, Tel. ; *Illavu*, Tam. ; *Letpan*, Burm.

A very large deciduous tree with a straight cylindrical stem and horizontally spreading branches in whorls : large trees are nearly always buttressed at the base. Bark smooth, grey, 0.7–1 in. thick, that of young trees and branches covered with large conical prickles, that of older trees often with somewhat widely separated longitudinal cracks. The leaves are digitate, with five to seven leaflets.

The *simal* tree attains very large dimensions, a height of 130 ft. and a girth of 12 ft. above the buttresses being not uncommon. When grown under forest conditions it soon loses its lower branches and forms a clean

bole sometimes 80–100 ft. in length to the lowest branch. Mr. Gamble¹ refers to a tree in Palamau which was 135 ft. high and 115 ft. in girth round the buttresses. A tree recorded from Travancore in 1909 had a girth round the buttresses at 5 ft. from ground-level of 42 ft., the girth above the buttresses, which averaged 20 ft. in height, being 15 ft. 4 in. Mr. J. G. F. Marshall² records a very large tree situated on shallow soil with a gravelly and free subsoil at an elevation of between 700 and 1,000 ft. on the summit of a small hill at the foot of the Coorg *ghats*, where the normal rainfall is 190 in. Its height was 195 ft., girth at 3 ft. from ground 102 ft., and at 30 ft. from ground 15 ft.; it had seven large buttresses which would have easily contained an elephant between any two of them. The wood is soft, light, whitish in colour and perishable, and soon becomes discoloured if not quickly sawn up. It is used for rough planking and for tea-boxes. Although not a first-class match wood, it has been used more than any other wood in India for the manufacture of a cheap grade of matches owing to its abundance and accessibility. The capsules furnish a silk-cotton used for stuffing pillows.

The economic value of the *simal* as a timber tree lies mainly in its rapid growth and volume-production, for although the actual value of the wood per cubic foot may be small, this tree may under favourable conditions yield returns higher than those yielded by trees with much more valuable timbers.

DISTRIBUTION AND HABITAT. Throughout India and Burma, except in the most arid tracts. It is most commonly found on flat alluvial ground near river-banks, where it is often gregarious (see Fig. 62). Here it grows fastest and reaches its best development on deep alluvial deposits containing a considerable proportion of sand. It is often found scattered in mixed usually deciduous forest and even in sal forest, and is a characteristic tree on grassy savannah lands, where it often becomes gregarious. It will grow on badly drained ground, but here the growth is comparatively slow and the development poor, the trees remaining stunted with tapering boles. In the Dehra Dun valley it is one of the commonest trees on patches of shallow soil overlying hard calcareous tufa; here it is stunted. Talbot says it grows in exposed situations on the hard trap of the Akrani (Satpurus) at 3,700 ft. altitude; the stems are often stout and short, with the branches shortened and curved upwards at the ends. It is often found in various unlooked-for situations; thus it penetrates for some distance into the Himalayan valleys and may be found scattered on the slopes of the hills, sometimes in very dry situations, up to about 4,000 ft. or even more. I have seen a tree at 5,000 ft. elevation above Mangoli in the Naini Tal hills, associated with *Quercus incana*. Its wide distribution is due to the fact that the cotton-covered seeds are carried by the wind to very considerable distances.

The *simal* occurs in regions showing a wide range of temperature and rainfall, but thrives best in a comparatively moist tropical climate. In its natural habitat, excluding places where it is found up to 3,000–4,000 ft. or more in the hills, the absolute maximum shade temperature varies from 95° to 120° F., the absolute minimum from 25° to 65° F., and the rainfall from 30 to 180 in. or more.

LEAF-SHEDDING, FLOWERING, AND FRUITING. In some cases, particularly

¹ Ind. Forester, vii (1881–2), p. 296.

² *Ibid.*, xiii (1887), p. 322.

in dry situations, the leaves may turn yellow and commence to fall in the beginning of December, the trees being leafless by the end of that month. Some trees, particularly in moist situations, may remain in full leaf till March. The new leaves appear in March or April. The large round dark brown buds become conspicuous in December. The showy scarlet flowers appear in January and February, and sometimes continue till March; the trees are usually leafless at the time of flowering, but if in leaf the flowers are as a rule not so numerous. The trees when in full flower present a striking blaze of colour; the fleshy petals are attacked by crows, minahs, and other birds, and when they fall to the ground they are eagerly devoured by deer. I have observed squirrels (*Sciurus maximus*) eating the flower-buds in quantities. Pollination is effected by bees, which visit the flowers in large numbers, as well as by birds, which seek the nectar or search for insects, and get their heads covered with pollen. Even martens (*Martes flavigula*) have been observed visiting the flowers in search of nectar.¹

The fruits develop very rapidly, sometimes reaching a length of 3 in. while there are still flowers on the tree; they ripen in April and May. The fruits are oblong woody five-valved capsules 4–6 in. long, which open usually while still on the tree, but sometimes after falling. The seeds, which are numerous, are surrounded by masses of white silky hairs, and are thus easily blown about by the wind. Strong dry winds are frequently prevalent at the time the fruits ripen, and where cotton trees are numerous the air is full of flecks of silk-cotton which are blown for miles, bearing the seeds with them. The seeds (Fig. 60, *a*) are 0.2–0.25 in. long, irregularly obovoid, dark brown, smooth, with a brittle testa: about 750 to 900 weigh 1 oz. Although the seeds are oily they retain their germinative power for some time if carefully stored. Tests carried out at Dehra Dun showed a fertility of 30 and 70 per cent. for seeds 1 year old, and 20 per cent. each for seeds 2 and 3 years old. Fresh seed always showed a higher percentage of fertility than old seed, and it is therefore advisable to use it whenever available. The seed, embedded in cotton, may be collected off the ground, or better still the capsules may be knocked off the tree when they are just about to open and placed in the sun, when they soon burst. A convenient method of separating the seed from the cotton is to place both in a large open basket. A round stick about 2 ft. long and $\frac{1}{4}$ to $\frac{1}{2}$ in. in diameter is prepared, and about 2 in. from one end of it two pointed cross sticks about 5 in. long are tied firmly to the long stick and at right angles to it and to each other. This end of the long stick is then pushed into the cotton and the stick is revolved rapidly in alternate directions by rubbing it between the palms of the hands: this causes the seeds to separate from the cotton and sink to the bottom of the basket.

Records for nine consecutive years in the Bengal Duars show that in that tract a good seeding may be expected annually. This is not the case in the United Provinces, where records for seven years indicate that an abundant crop of seed may be expected about once in two years.

GERMINATION (Fig. 60, *b-f*). Epigeous. The testa splits and the radicle emerges from the narrow end of the seed and descends. The hypocotyl elongates, arching at first, and in straightening carries above ground the

¹ G. B. F. Muir in Journ. Bomb. Nat. Hist. Soc., xxiv (1916), p. 589.

cotyledons, which are much crumpled in the seed but soon expand. The testa is either left in the ground or carried up over the cotyledons, falling with their expansion.

THE SEEDLING (Fig. 60).

Roots : primary root long, at first thin, afterwards thickening greatly and becoming fleshy, terete, tapering upwards and downwards from the fleshy part, at first white, afterwards yellow or light brown: lateral roots few or moderately numerous, chiefly on upper part of main root. *Hypocotyl* distinct from root, 1.2–2.4 in. long, at first thicker afterwards thinner than taproot, terete, tapering slightly upwards, white and delicate at first, afterwards becoming green and tougher, glabrous or minutely pubescent. *Cotyledons* : petiole 0.1–0.2 in. long, channelled above, glabrous: lamina 1–1.2 in. by 1 in., foliaceous, cordate, acute, entire, green, glabrous, palmately 5-veined from base, secondary veins reticulate. *Stem* erect, terete, at first tough, later woody, green becoming yellowish brown, glabrous; internodes 0.2–0.5 in. long. *Leaves* alternate, first one or two simple, followed by a few (up to five) 3-foliate leaves, followed by several 5-foliate digitate leaves, sometimes with one or more 4-foliate leaves intervening; in second season leaves 5- to 7-foliate. *Stipules* 0.2 in. long, linear lanceolate. Simple leaves with petiole 0.5–1.2 in., terete or slightly flattened above, glabrous, lamina 1.5–2.7 in. by 0.9–1.2 in., ovate or cordate, acuminate, glabrous, venation reticulate. Trifoliate leaves with common petiole 3–5 in. long, leaflets sessile or sub-sessile, glabrous, lateral pair 2–4.5 in. by 0.8–1.8 in., unequally ovate lanceolate, acuminate, terminal leaflet 3–7 in. by 1–2 in., elliptical ovate or obovate lanceolate, acuminate.

The growth of the seedling during the first season is slower than it is subsequently. At Dehra Dun seedlings attained a height of 3–6 in. by the end of the first season, while those which were regularly weeded and watered grew rapidly during the second season, some reaching a height of 5½ ft. by the end of the season: in more tropical climates the growth is even faster. On stiff soil and on other unfavourable ground the seedlings remain small for two or three years or more, growing only a few inches a year. In dry localities they may die back annually for a few years before establishing themselves and commencing upward growth. The seedlings are tender to frost, and this dying back may also take place in frosty localities, the young plants being killed back to ground-level in the winter and producing new and stronger shoots next spring. Prickles, which are at first small, commence to be produced on the stems of vigorous seedlings in the second season: in more backward seedlings they do not appear until later. In northern India new growth starts in April or May and continues till October; the growth is greatest from June to August. A feature of the seedling is the long thick fleshy taproot, which in vigorous plants may reach a length of 1 ft. or more in two months and 1½ ft. or more by the end of the first season. Seedlings are subject to the attacks of various animals; hares nibble the stem, rats gnaw the taproot, and pigs and porcupines grub up the roots.

SILVICULTURAL CHARACTERS. The cotton tree is a strong light-demander. It resists slight frosts, but is affected by severe frosts in northern India. In famine years it has been found to be unaffected by drought. Growing as it does in savannah tracts it is subject to severe burning: in the seedling and sapling stage it is repeatedly burnt back, but has good power of recovery from the base, and once it is established its thick bark enables it to resist damage by fire better than most species. It benefits greatly, however, from

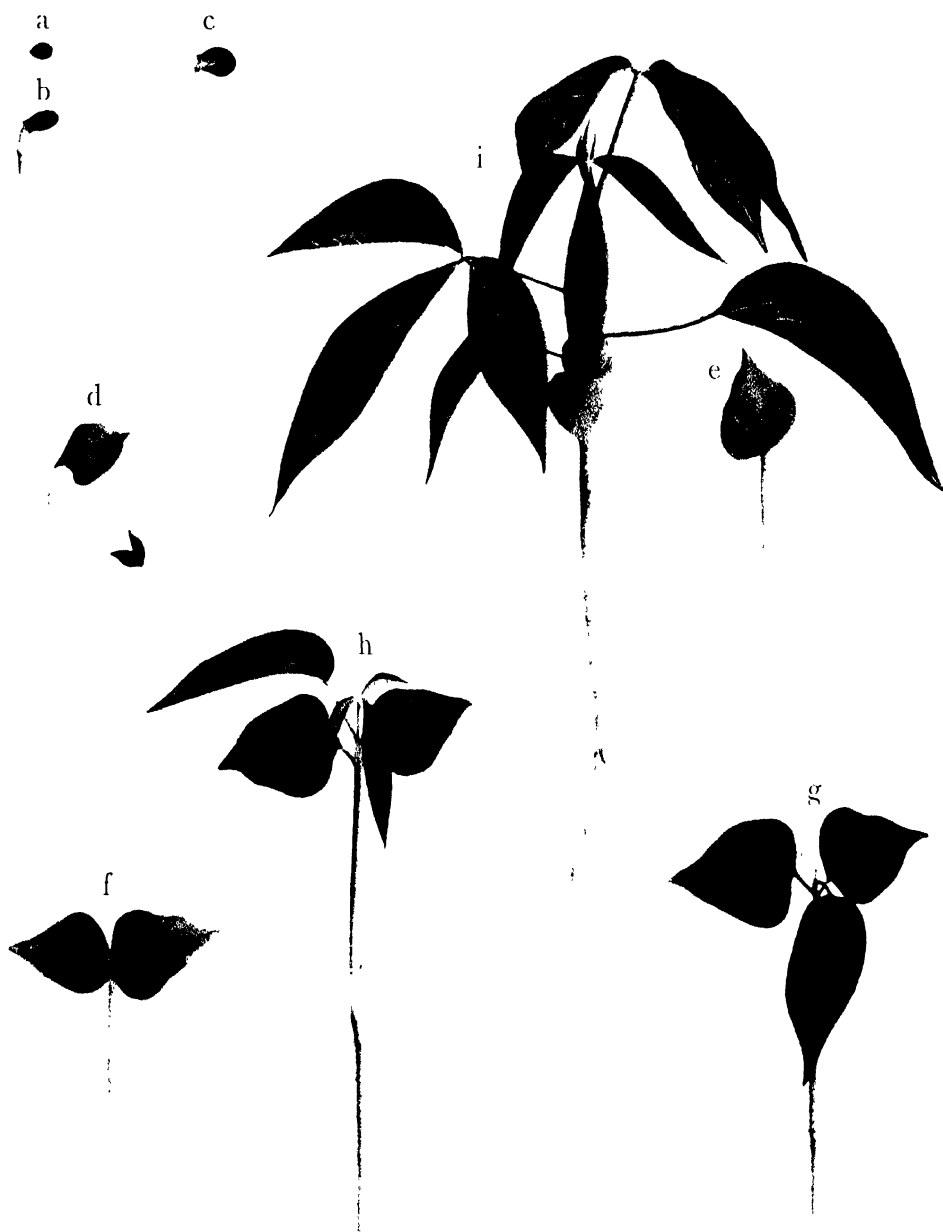


FIG. 60. *Bombax malabaricum*—SEEDLING $\times \frac{1}{8}$

a—Seed b - f—Germination stages g - i—Development of seedling to end of first season

fire-protection. It coppices in its early years but not later, and is not known to produce root-suckers. It suffers from grazing, and in its young stages benefits much from the protection of thorny bushes.

NATURAL REPRODUCTION. The spread of the seed by wind and the consequent wide distribution of the tree have been noted. Natural regeneration establishes itself freely on new alluvial flats, savannahs, and other open spaces. In northern India it is one of the first trees to make its appearance on alluvial ground in the stage subsequent to that in which the land is occupied by *Dalbergia Sissoo* and *Acacia Catechu*. In heavily grazed areas the saplings establish themselves freely under the protection of dense clumps of *Zizyphus Jujuba*, *Z. Xylopyrus*, and other armed shrubs, or in tussocks of coarse grass, where they are out of reach of cattle. Similarly it is often seen making its way through hedgerows and thickets of *Acacia Catechu*. In the Central Provinces *Zizyphus Oenoplia* furnishes the same useful protection, and *Bombax* regeneration sometimes makes its way in quantity through thickets of this otherwise noxious climber. It is owing to this early protection and to the capacity of the seedlings for pushing their way through clumps of bushes that the *simal* frequently becomes gregarious even on land subject to heavy grazing. Experiments have shown that dense weed-growth greatly hampers the development of the seedlings, and it is therefore probable that several years are occupied in their pushing their way through shrubby growth if this is at all dense. Fig. 61 shows typically the manner in which the saplings establish themselves in thickets of shrubs in grazed areas, while Fig. 62 shows a later stage of growth on an adjacent area of the same type. On abandoned cultivation saplings often spring up in quantity and grow rapidly. The beneficial effects of fire-protection on the natural reproduction of this tree may be observed in any of the fire-protected tracts in which it grows, for although once established it has considerable power of resistance to fire, numbers of seedlings are destroyed for every one which becomes established: in many places, indeed, the introduction of fire-protection is followed by a plentiful crop of natural reproduction wherever there is sufficient light.

ARTIFICIAL REPRODUCTION. Numerous experiments in the artificial reproduction of the *simal* have been carried out within recent years at Dehra Dun and on a larger scale in Assam, the United Provinces, and elsewhere. The most satisfactory method of raising plantations has not yet been determined, but the results detailed below indicate that so far the greatest success has been attained, in the order given, by

- (1) irrigated line sowings, which, however, will probably prove too expensive in practice;
- (2) sowings in conjunction with field crops; and
- (3) unirrigated weeded line sowings.

Transplanting of nursery-raised plants has not hitherto proved much of a success.

The financial success of plantations of soft-wooded species of comparatively small value must depend largely on a rapid rate of growth, or, in other words, on the careful selection of a site, intensive weeding in the early stages, and regular thinnings to promote development. Above all, stiff clay or shallow

rocky soil should be avoided, for not only will the growth and development be poor, but the seedlings will be liable to die back for some years before establishing themselves, owing on the one hand to bad drainage and on the other to drought: the same dying back occurs in frosty localities, which should also be avoided. On water-logged ground failure is almost certain to result owing to the tendency of the thick fleshy taproot to decay in such localities. Deep porous alluvium with a considerable proportion of sand will produce the best growth. A contingency by no means negligible is the damage done by animals, especially pigs, which root up the seedlings, and rats, which gnaw through the thick fleshy roots.

Spacing. The best spacing in plantations has not yet been determined. Close planting is unnecessary, owing to the rapid growth of the trees and the space required by them for development. In Assam spacings of 20 ft. by 20 ft. and 24 ft. by 12 ft. have been tried, but this is perhaps somewhat wide, hardly allowing sufficient margin for casualties and for the removal of misshapen stems. Ordinarily a spacing of about 12 ft. by 12 ft. should meet requirements. In line sowings a distance of about 15 to 18 ft. between lines will probably be found suitable, and 1 oz. of seed will be found sufficient for about 250 ft. of line.

Rotation and yield. The rotation, depending on the rate of growth, must vary greatly with the locality. Under optimum conditions, judging from the rate of growth of natural trees, a girth of 6 ft. may be expected to be reached in twenty years; it would, however, be quite unsafe to count on such a short rotation in actual practice, even in very favourable localities, since time must be allowed for the establishment of the seedlings as well as for unforeseen contingencies. Even in localities of the best quality it would be unsafe to reckon on a rotation of less than twenty-five years to produce an average girth of 6 ft., while under ordinary favourable conditions a rotation of thirty years might be reasonably estimated. Where the seedlings tend to die back in early youth or to establish themselves slowly, a suitable period would have to be added to the actual growing rotation. On unsuitable localities, such as badly drained areas, or where there is risk of damage by frost, drought, fire, grazing, or other injuries, an estimate of the rotation could not be anything but conjectural, and indeed it may be accepted as fairly certain that *simal* plantations cannot be expected to pay in such localities.

The actual yield per acre will vary with the quality of the locality, but judging from measurements of natural trees it is estimated that a well-tended plantation grown on a rotation sufficient to produce trees of 6 ft. girth in a favourable locality should yield about 4,400 cub. ft. of utilizable timber per acre (excluding bark and waste wood): this allows for 3,500 cub. ft. in the final yield (trees 6 ft. in girth) and 900 cub. ft. of intermediate yield (trees 4½–6 ft. in girth cut out in thinnings). These figures are not based on measurements in actual plantations, which are not yet available, and should therefore be regarded as only provisional.

Results of experiments. The various experiments hitherto undertaken in the artificial propagation of *simal*, with the results attained, are as follows:

1. *Early tending.* The question of early tending may be considered first, as it affects all forms of artificial reproduction. Experiments at Dehra Dun



FIG. 61. *Bombax malabaricum*, young trees (leafless) establishing themselves under the protection of a dense growth of *Zizyphus Jujuba* on heavily-grazed land, Dehra Dun, United Provinces.



FIG. 62. *Bombax malabaricum*, trees growing gregariously on alluvial land, Dehra Dun, United Provinces.

have demonstrated the necessity for weeding thoroughly round the young plants during the first two years and keeping the soil loosened where it is liable to cake; thereafter it is necessary to keep the plants free from all overhead cover until they are thoroughly established. In line sowings such weedings were found to have remarkable results: thus, the height-growth in weeded lines during the first two years was twice and four times that in unweeded lines in irrigated and unirrigated sowings respectively, while the vigour of the weeded plants was far greater than that of the unweeded plants, the latter being thin and lanky and often unable to stand erect without support, while a large proportion were killed out by suppression. Another important result of weeding is the fact that in the weeded lines the plants are less liable to damage by frost, no doubt owing not only to the freer circulation of air, but also to the greater vigour of the plants. Weeding should commence early in the first rains, and should be continued at frequent intervals as required. The same applies to the loosening of the soil, which should be continued during the following winter and hot season: this operation can be done expeditiously with a hand plough or a small weeding fork. A second measure of importance in line sowings is the thinning out of plants where they are congested, the more vigorous individuals being left and the weaker ones removed: opportunity should be taken during this operation to utilize the best of the surplus plants to fill up gaps, otherwise the most expeditious method of thinning out the seedlings is to drive a *kurpa* or large knife down through the taproot so as to sever it, and pull the plant up. This thinning out of seedlings should commence not later than the early part of the first cold season, and should be repeated about once a year for the first two or three years, leading on to regular thinnings at longer intervals.

2. *Propagation by cuttings.* Experiments in propagation by cuttings have not justified the employment of this method in practice. In Assam, cuttings about 6 ft. long and 2 in. in diameter were found to strike well, but the subsequent percentage of mortality was high. At Dehra Dun smaller cuttings raised in the nursery were also found to strike well, but a very large percentage died subsequently: they were found to do best if put down early in the rains in a slanting position, only a few inches (including at least one bud pointing upwards) being left above ground in order to produce a straight new shoot from near ground-level.

3. *Transplanting nursery-raised seedlings.* Experiments at Dehra Dun have shown that although with care nursery-raised seedlings can be transplanted without much difficulty, they are apt to receive a check to their growth in the process, and the results have been decidedly inferior to those attained by weeded line sowings *in situ*. In the nursery the seed should be sown in drills before or at the commencement of the rains in well-raised beds on light soil containing a good proportion of sand, and should be lightly covered with earth. If the plants are to be transplanted in the first year, a distance of about 8 in. between drills will suffice, but if they are to be kept in the nursery till the second year, the distance should be not less than 1 ft. The beds should be regularly watered in dry weather and weeded, the soil being kept loosened. The seedlings ordinarily appear about one to three weeks after sowing, and are ready for planting out one to two months later; even then the taproot is

often 8 to 12 in. long, but with reasonable care there is no difficulty in transplanting into pits. The plants may be kept in the nursery till the second rains, by which time they will have reached a considerable size and will require to be 'stumped' before transplanting. For this purpose the stem should be pruned down to about 3 in. from ground-level, and the taproot pruned down to about 9 in. in length; this treatment has not been found to do any material harm to the seedlings, and is necessary owing to the large size of the taproot. Experience in Assam has shown that plants which have been transplanted three or four times in the nursery, and are then removed to the plantation, stand planting out best, but make little progress afterwards, whereas those which are removed straight from the seed-beds, although they are more susceptible to the shock of planting out and produce more casualties, show quicker subsequent growth. The latter condition is certainly preferable to the former, and the increased mortality can be counteracted by closer planting. Further experiments are desirable in the transplanting of stumped plants in the second or even the third rains.

4. *Irrigated line sowings.* Experiments with irrigated line sowings at Dehra Dun have proved remarkably successful, the plants reaching a maximum height of nearly 10 ft. in $2\frac{1}{2}$ years and showing vigorous development. It is doubtful, however, if the expense of irrigation could be justified on a large scale by the corresponding increase in growth, particularly as the results attained by experimental weeded unirrigated line sowings have not been greatly inferior to those attained by irrigated sowings: on the other hand, the cost could be recouped to some extent by growing field crops between the lines in the early years of the plantation. In carrying out irrigated line sowings the seed is lightly dibbled in along the base of the ridge of earth thrown up from irrigation channels, a flat space of a few inches being left between channel and ridge. The channels should be 1 ft. deep with an average width of 1 ft., and should be cleared of silt periodically. The importance of frequent weeding and of thinning out congested seedlings has already been alluded to. Fig. 63 shows the result of irrigated line sowings at Dehra Dun.

5. *Unirrigated line sowings.* This form of establishing *simal* plantations is one which is applicable mainly to open tracts not covered with tree-growth, since it is doubtful if it would pay to clear and burn forest land for the establishment of *simal* plantations without the aid of field crops. This system has been tried experimentally at Dehra Dun with considerable success. Two methods of preparing the lines were tried, one in which the ground was dug up with a hoe to a width of 1 ft. and levelled, and the other in which a double furrow was made with a plough run once up and down the line. There was nothing to choose between the respective results, while the ploughing was cheaper than the hoeing; on stiffer soil, however, it would no doubt be found advantageous to break up the clods on the ploughed line. Subsequent weeding along the lines was, as already stated, found to be essential to success, while loosening of the soil in the first year or two had a marked effect on the development of the plants. After $2\frac{1}{2}$ years the maximum height in the weeded lines was nearly 10 ft., though neither the average height nor the general development of the plants was quite equal to that of the irrigated line sowings.

Experimental line sowings in the large grassy blanks (*phantas* and *chandars*)



FIG. 63. *Bombax malabaricum*, irrigated weeded line sowings, end of fourth season, Dehra Dun, United Provinces.

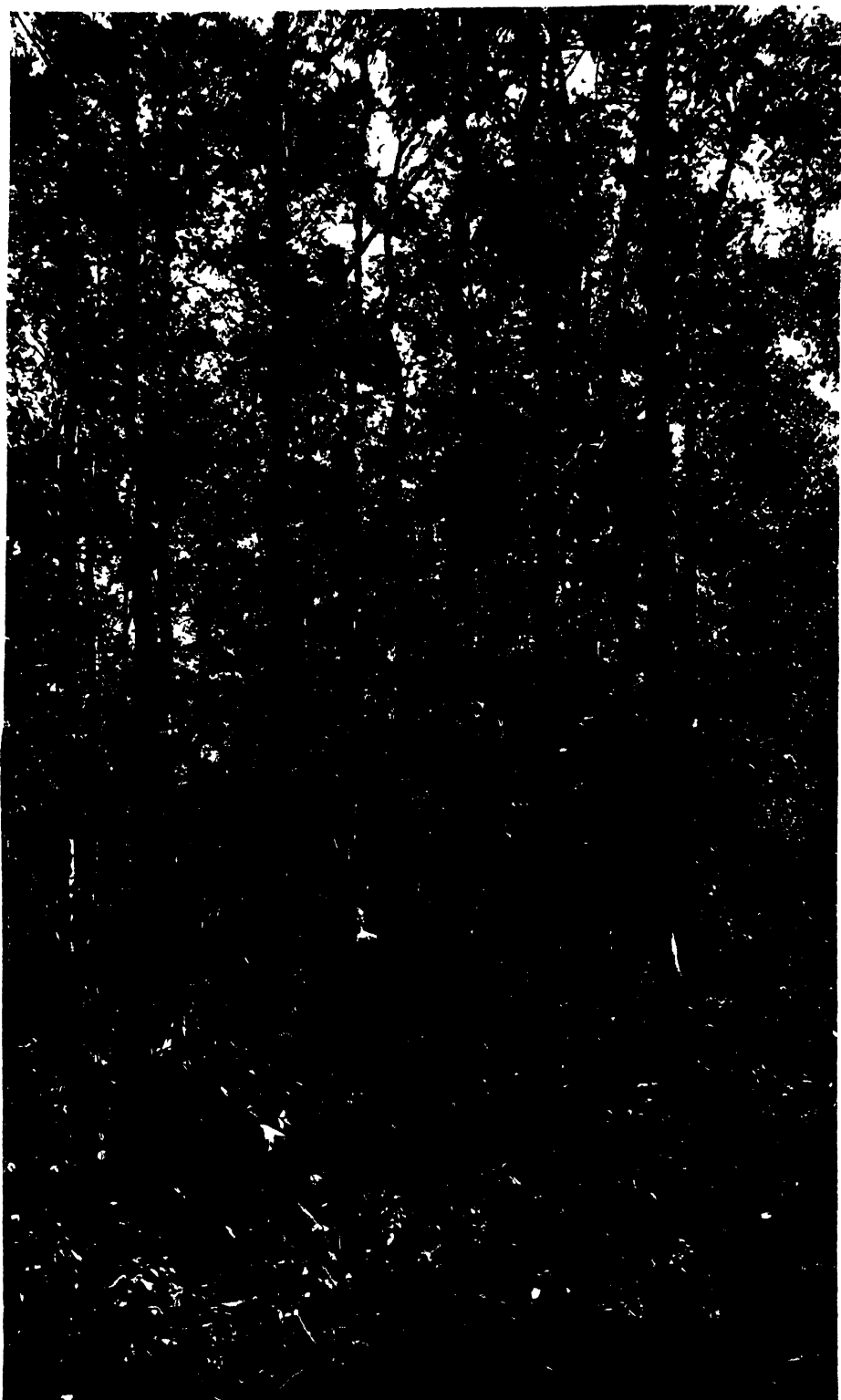


FIG. 64. *Heritiera Fomes* pure forest after a thinning, Sundarbans.
Note pneumatophores on the ground.

of the Kheri district, Oudh, have been in progress for some years, with varying results. Numerous failures have occurred, some owing to pigs and rats, some to frost, some perhaps to the stiffness of the soil or want of drainage in places, and some to damage by fire. In the earlier years the plants also suffered from the attacks of insects, which damaged the leading shoots. The most fruitful cause of failure in the earlier experiments, however, was probably the fact that weeding was not carried out, for the success has been greater since regular weeding was instituted. These areas are covered with a heavy growth of high savannah grass, and unless the lines are kept clear a considerable proportion of the seedlings are liable to be killed by suppression.

6. *Plantations raised with unirrigated field crops.* In experiments at Dehra Dun, line sowings in combination with field crops have given greater success than any other form of artificial reproduction without the aid of irrigation. The field crop employed was the lesser millet or *mandwa* (*Eleusine coracana*), and the ground being fertile cleared forest land it formed a dense crop $3\frac{1}{2}$ ft. high. The crop was sown towards the end of May and reaped in October, and the lines of *simul* were sown immediately after the sowing of the crop. Two separate methods were tried, one in which the field crop was sown evenly over the whole area, the *simul* seedlings coming up under its shade, and the other in which the field crop was sown in the spaces intervening between the lines, a clear strip $1\frac{1}{2}$ to 2 ft. wide being left along the lines. The latter system was much more successful than the former, and is the one recommended for adoption: the cultivator keeps the lines weeded and the soil loosened during the first rains, and the light admitted to the clear strip causes the plants to develop satisfactorily. Where the crop was sown evenly over the whole area without leaving clear strips for the *simul*, the latter became weak and lanky and dropped their leaves prematurely with the sudden exposure when the crops were reaped.

In Assam, *simul* plantations have recently been formed in combination with rice cultivation in *jhums*, that is, temporary forest clearings in which the felled material is thoroughly burnt prior to the sowing of the crops. The results have been very encouraging, and in some cases the plantations have cost nothing to form, the *simul* seed having been sown and the young plants tended free by the cultivators in return for permission to cut *jhums* in reserved forests. Among the earlier experiments may be mentioned a plantation of 80 acres at Kerwa in the Lakhimpur district, in which seed was sown in 1914. Two years later the plantation was reported to be practically fully stocked, there being 11,036 young trees averaging 12 ft. in height. In the North-East Frontier district there were about 450 acres under *simul* in 1917.

The system adopted has been described as follows by Babu R. N. De : ¹

‘ Early in June or July, varying according to the time when the *Simul* seed ripens, it is collected by the Forest Department and distributed to the villagers, who, at this time of the year, sow rice in their newly cleared “*jhums*”. Before the rice is sown they have to put up stakes in their *jhums* at 26' x 26' and then the rice is sown with the *Simul* seed, the latter at each stake. Sometimes the rice is sown before the *Simul*. Five to ten seeds are put at each stake; this is done to be perfectly sure that there will be no failure. In some cases the staking is done under the supervision of Forest Officers, but in the

¹ Ind. Forester, xliv (1918), p. 517.

North-East Frontier District the Miris do it themselves under the instruction of Forest Officers, as the Forest staff is insufficient to do the staking in a number of villages, scattered over a considerable area. If the seeds are good, they germinate freely within six or seven days. Though Simul does not grow so quickly as the rice plant, it is not at all injured by the latter. If, at any stake, no Simul seed has germinated, seedlings are transplanted from those stakes where there are more than one.

As the transplantation is carried on, only the best seedling is kept at each stake and the rest are transplanted if necessary, or removed. After the rice has been cut, the area is cleared and mustard, rye, potato, etc. are grown in the jhums. By this time the Simul plants are 1'-2' high. Next year in the rains, the rice is sown again after clearing the area of weeds, and this rice is weeded once or twice during the rains. In the rains the Simul plants grow very vigorously, some of them attaining 6' in height. Having received such careful tending from the very start, no amount of weeds and fast growing shrubs can hinder their growth and by the winter of the second year most of the plants are 8' and over in height; Mr. Jacob, Deputy Conservator of Forests, has measured seedlings which have attained 15' in height in their second cold weather. The Miris usually abandon their jhums at the end of the second year after growing mustard, etc. The plants now need no looking after and can fend for themselves, but if the land is cultivated for the third year, the plants do still better. The Miris can grow crops underneath Simul without difficulty, as it has a very light crown.

As from its habit Simul does not grow any more branchy when isolated, and as the height growth of this tree is not appreciably stimulated by growing the plants closer together, thinning and cleaning operations are unnecessary. It was found that when planted 12' x 24', branches were interlacing by the third year; this is why plants are put in 26' x 26'. Much knowledge has yet to be gained as to the best distance at which plants should be spaced.'

SILVICULTURAL TREATMENT. With protection from fire and from excessive grazing, the tree springs up in abundance on suitable ground, but if permanent supplies of timber are required in regular quantities at cheap rates it is doubtful if any system would be as suitable as that of clear felling with artificial regeneration on a definite rotation. Experience has shown that where the demand for the wood is keen, as in certain districts in Assam, where it is used for tea-boxes, the supplies of natural *simal* may easily become exhausted in spite of the readiness with which it regenerates.

RATE OF GROWTH. Under favourable conditions the rate of growth of *simal* is very fast, a growth of two rings per inch of radius, representing a mean annual girth increment of over 3 in., being by no means unusual. In less favourable localities the growth is considerably slower. Mr. S. E. Peal¹ states that a tree felled in Assam in 1883 had sixteen annual rings on a radius of 21 in., the rings varying from $\frac{1}{2}$ in. to $2\frac{1}{4}$ in. in width. This represents a mean annual girth increment of 8.2 in., at which rate a tree would reach a girth of 6 ft., excluding bark, in about nine years; this would appear almost incredible were it not that the tree grew on the site of former coolie lines which the writer states were known to him. In estimating the age of *simal* in localities where the seedlings die back owing to frost or other causes, the addition of some years for the time required for the establishment of the seedling is a necessary precaution. The annual rings in *simal* are clearly visible, and the rate of growth can thus be readily ascertained from ring-countings on stumps.

¹ Ind. Forester, ix (1883), p. 539.

Mr. E. Marsden ascertained from an examination of six trees at Dehra Dun that each internode represented a year's growth; if this holds good generally, then it should be possible to estimate the age of standing trees fairly accurately by counting the number of internodes between whorls of branches.

2. *Bombax insigne*, Wall., including *B. cambodiense*, Pierre, and *B. anceps*, Pierre.

The sub-species and varieties of this tree have not yet been fully determined. Gage¹ describes the following:

I. Sub-sp. *genuina*, Prain.

(a) Var. *typica*. A large tree reaching a height of 100 ft. and a girth of 20 ft. Bark more or less covered with conical prickles. Leaves digitate with 5-12 leaflets. Flowers with red petals about 5½ in. long. Capsules 6-8 in. long by 1.6 in. in diameter.

Loc. Chittagong, Arakan, Burma (Bhamo, Pegu and Arakan Yoma, Tenasserim, N. Shan States). Vern. *Didu-pyu*, Tenasserim; *Shin*, Tavoy; *Sit-pan bewip*, N. Shan States; *Didók*, *kókhè*, Pyinmana.

(b) Var. *Wightii*, Prain. A large tree with more or less prickly bark. Leaflets 5-6 or more. Petals red, about 3½ in. long. Capsules about 5-7 in. long by 2 in. in diameter.

Loc. Burma (Shwegyin): Indian Peninsula on the W. Ghats. Vern. *Didu*, Burm.

II. Sub-sp. *anceps*, Prain.

(a) Var. *vera*. Syn. *B. anceps*, Pierre. A lofty tree reaching a height of 100 ft. and a girth of at least 16 ft. Bark greyish, more or less prickly when young. Leaflets 5-7. Petals red or white. Capsule woody, dark brown, 3¼-4 in. long with five very prominent rounded ridges.

Loc. Burma (Pegu and Arakan Yoma, Upper Burma, N. Shan States, Salween). Vern. *Didu-pyu*, *didók*, Burm.; *Kowa*, Karen.

(b) Var. *cambodiensis*. Syn. *B. cambodiense*, Pierre.

A tree reaching a height of about 80 ft. Bark grey, covered with conical spines. Leaflets usually seven.

Loc. Upper Burma, Cambodia.

Of other varieties distinguished by Prain² may be mentioned var. *andamanica*, so far found only in the Andaman Islands, and differing from the normal type in having narrow leaflets.

If any silvicultural distinctions exist among the different sub-species or varieties, they have not yet been studied, and the species may be considered as a whole. Generally speaking this is a large deciduous tree with grey bark, which in youth at least is covered with conical prickles. In dimensions it probably equals *B. malabaricum*, which it also resembles somewhat in general appearance, the chief superficial distinction being that *B. insigne* has larger flowers and usually more numerous leaflets. In Burma its usual name is *didu*, sometimes *didók* (or *kókhè* in Upper Burma for var. *cambodiensis*). The wood is superior to that of *B. malabaricum*, and, as in the case of that species, the capsules furnish a silk-cotton.

DISTRIBUTION AND HABITAT. The natural home of this tree is in Burma,

¹ Ind. Forester, xxxiii (1907), p. 115.

² Journ. Asiat. Soc. Beng., lxii, 1893.

the Andamans, Chittagong, the Malay Peninsula, and the Western Ghats from North Kanara southwards. In Burma it is most commonly found in the upper mixed deciduous forests associated with teak and its usual companions on well-drained often hilly ground ; here it reaches large dimensions. In Burma it is not so gregarious as *B. malabaricum*, and is typical rather of hilly or undulating ground than of alluvial flats. Talbot says that in North Kanara it is gregarious from the coast upwards to the crest of the *ghats*, that it is also found in the Konkan and Deccan districts, and often occurs on laterite. In the Andamans it is common in deciduous forests on well-drained hilly ground, usually on micaceous sandstone, associated with *Pterocarpus dalbergioides*, *Lagerstroemia hypoleuca*, *Sterculia alata*, *S. villosa*, *Artocarpus Chaplasha*, *Albizzia Lebbek*, and other deciduous trees. It also extends along with some of its usual companions into the evergreen or semi-evergreen forest on hill slopes, associated with *Dipterocarpus* spp. and other trees characteristic of these types.

Bombax insigne is essentially a tree of tropical regions, where the absolute maximum shade temperature varies from 96° to 110° F., the absolute minimum from 42° to 60° F., and the rainfall from 40 to 150 in. or more.

LEAF-SHEDDING, FLOWERING, AND FRUITING. In Burma the tree usually sheds its leaves early in December, and remains leafless till May. The flowers, usually red, sometimes white, appear at the end of December and in January, the capsules ripening in April. In the Andamans the capsules commence to ripen in March. The seed, enveloped in silky cotton, is dispersed by wind as in the case of *B. malabaricum*. Seeds received from the Andamans were 0.25 in. by 0.2 in., obovoid, dark brown, smooth, with a fairly hard but brittle testa : in two separate samples, 330 and 570 seeds respectively weighed 1 oz. The seeds are oily. Gage¹ describes seeds of sub-sp. *genuina* var. *Wightii* as pyriform compressed 8 mm. by 5 mm. (i.e. 0.3 in. by 0.2 in.), and those of sub-sp. *anceps* var. *vera* as ovoid compressed 8 mm. by 5 mm. The seed keeps indifferently ; a sample kept for one year showed a fertility of only 5 per cent.

SILVICULTURAL CHARACTERS. The silvicultural characters of this tree have not yet been studied.

3. *Bombax scopulorum*, Dunn.

This is a tree of the forests of Travancore described by Bourdillon, under the name of *B. insigne*, as a 'small tree having the appearance of the cotton tree but never attaining its size'.

2. KYDIA, Roxb.

Kydia calycina, Roxb. Syn. *K. fraterna*, Roxb. ; *K. Roxburghiana*, Wight. Vern. *Pula*, *puli*, *patha*, Hind. ; *Kakahi*, Oudh ; *Barranga*, C. P. ; *Kopasia*, Uriya ; *Warang*, *iliya*, Mar. ; *Bellaka*, *bendi*, Kan. ; *Potri*, *pandiki*, Tel. ; *Dwabók*, *myethlwa*, Burm.

A moderate-sized deciduous tree with grey bark exfoliating in irregular flakes or long strips. A tree with soft white wood, of little value commercially, but important owing to its abundance in certain types of forest.

DISTRIBUTION AND HABITAT. Common throughout India and Burma, chiefly in mixed deciduous forests ; not in arid regions. In the sub-Himalayan

¹ loc. cit.

tract abundant in many of the mixed forests, and in sal forest : in Burma frequent in the lower mixed deciduous forests of the plains.

LEAF-SHEDDING, FLOWERING, AND FRUITING (observations made in north India). The leaves commence to fall at the end of November, and the tree is leafless from January or early February to late April. The tree flowers and fruits at an early age. The flowers appear in September–October, and the masses of greenish white or pale lilac blossoms make the trees a conspicuous sight at this season. By the middle of November the fruits begin to form ; they ripen from early January to late March, and by April most of them have fallen. The fruit is a three-valved capsule subtended by the dry persistent calyx : the fruiting panicles, which are brittle, fall off whole or in pieces or are blown off by the wind. The seeds (Fig. 65, *a*) are greyish brown, 0.1 in. diam., reniform, furrowed with fine striations, with a fairly hard testa ; about 900 weigh 1 oz. The seeds are best obtained by collecting the dry fruiting panicles about February, rubbing them in a cloth or bag, and separating the seeds by winnowing. Tests carried out with different samples of seed have shown that the percentage of fertility is usually low.

GERMINATION (Fig. 65, *b–d*). Epigeous. The testa splits and the radicle emerges and descends. The hypocotyl elongates, arching somewhat, and in straightening raises above ground the cotyledons enclosed in the testa, which falls to the ground with the expansion of the cotyledons.

THE SEEDLING (Fig. 65).

Roots : primary root in the first year moderately long and thick, terete, tapering, in the second year in vigorous plants long (sometimes over 2 ft.). thick and fleshy : lateral roots moderate in number, fibrous, distributed down the main root. **Hypocotyl** distinct from the root, 0.3–0.5 in. long, terete, fusiform or tapering upwards, white turning green, minutely pubescent. **Cotyledons** : petiole 0.25–0.3 in. long, pubescent : lamina 0.3–0.45 in. by 0.3–0.5 in., foliaceous, orbicular, base truncate or slightly cordate, entire, sparsely pubescent. **Stem** erect, terete, pubescent ; internodes 0.4–1.2 in. **Leaves** simple, alternate, petiolate, earlier leaves small, the size rapidly increasing. Stipules up to 0.1 in. long, linear. Petiole 0.4–1.5 in. long, pubescent. Lamina 0.4–2.5 in. by 0.4–2.5 in., orbicular cordate, apex acute or rounded, crenate or crenate dentate, dark green when young, becoming paler green, pubescent, palmately 5-veined.

The growth of the seedling is slow during the first season, but plants regularly weeded and watered at Dehra Dun attained a height of nearly 4 ft. by the end of the second season. On stiff soil or in heavy weed-growth the development is slow, seedlings under these conditions having attained a height of 1 in. and 9 in. by the end of the first and second seasons respectively. In northern India the seedlings are leafless during February and March, new growth commencing towards the end of March or in April.

SILVICULTURAL CHARACTERS. Although it stands moderate shade in youth, the tree is a decided light-demander. It is comparatively short-lived ; its rapid growth enables it to push its way through gaps till it reaches a height of 30–40 ft. or more, after which it is overtaken and suppressed by larger and longer-lived trees. It is a useful nurse for the sal, but requires to be cut out where it tends to get the upper hand. It is fairly frost-hardy, both in the seedling stage and later : although it suffered to some extent in the severe frost of 1905 in northern India, it escaped more lightly than many other species.



FIG. 65. *Kydia calycina*. Seedling $\times \frac{3}{4}$.
a, seed; b-d, germination stages e-h, development of seedling to end of first season.

In the abnormal drought of 1907 and 1908, which caused severe damage to the sal forests of Oudh, it proved to be a decidedly hardy species.

It coppices well and produces root-suckers. The average number of coppice-shoots per stool, obtained from countings in coppice coupes in Gonda and Gorakhpur, United Provinces, and compared with sal and *Terminalia tomentosa* in the same coupes, was found to be as follows :

Age		2 yrs.	3 yrs.	5 yrs.	9 yrs.	11 yrs.	13 yrs.
Average No. of shoots per stool.	<i>Kydia calycina</i>	1.7	1	1.33	3	1	1
	<i>Shorea robusta</i>	1.8	1.11	1.28	1.34	1.36	1.18
	<i>Terminalia tomentosa</i>	4.7	—	2.53	2.46	1	—

NATURAL REPRODUCTION. Although the seeds have a comparatively low germinative power they are produced in large quantities. Experiments at Dehra Dun indicate that germination is far more successful in fairly moist places shaded from the sun than in dry open situations, where the seed usually fails to germinate. Under natural conditions in the early rains the light seeds are often washed into heaps mixed with dead leaves and loose soil ; here they obtain conditions favourable to germination, which takes place during the first two months of the rains. The seedlings are very liable to damage by crickets, which bite the stems off and kill the seedlings. Although the development of the seedling is slow during the first season, it is vigorous during the second and subsequent years, in consequence of which the tree tends to become invasive under favourable conditions.

ARTIFICIAL REPRODUCTION. Experiments at Dehra Dun showed that direct sowing does not give much success owing to the low germinative power of the seed. Transplanting is successful if carried out in the first rains with seedlings 2-3 in. high raised in seed-beds. In the second rains plants raised in the nursery are too large to transplant successfully, either with entire roots or with pruned stems and roots.

RATE OF GROWTH. The rate of growth is rapid. Natural untended seedlings in an experimental plot near Kotdwara in the United Provinces attained a height of 25 to 30 ft. in five years. In coppice coupes two years old in Gonda division, United Provinces, out of 17 species it was found to be surpassed by one species only, namely *Careya arborea*, which had coppice-shoots averaging 12 ft. in height as against 10.6 ft. for *Kydia* and 7.6 ft. for sal. In one-year-old coppice coupes in Bhandara, Central Provinces, the average height of *Kydia* shoots was 5 ft. 7 in., other measurements being : teak 7 ft. 1 in., *Xylia* 6 ft. 8 in., *Acacia Catechu* and *Lagerstroemia parviflora* 6 ft. 4 in., *Diospyros Melanoxylon* 5 ft. 1 in., and *Bassia latifolia* 4 ft. 3 in. Measurements recorded by Mr. A. F. Broun in coppice coupes at Bullawala, Dehra Dun, in 1886, gave the following results for *Kydia* and sal :

Age		8 yrs.	9 yrs.	9 yrs.	10 yrs.
Average height	<i>Kydia</i>	18 ft. 6 in.	17 ft. 5 in.	15 ft.	18 ft. 2 in.
	Sal	16 ft. 2 in.	13 ft. 6 in.	16 ft.	11 ft.
Average girth	<i>Kydia</i>	6.9 in.	9.7 in.	7 in.	7.4 in.
	Sal	8.3 in.	8.7 in.	8.6 in.	5.9 in.

It is probable that the tree reaches its maximum dimensions at a comparatively early age, though the exact age has not been determined.

3. THESPESIA, Correa.

Thespesia populnea, Corr. Tulip tree, portia tree. Vern. *Poresh*, *dumbila*, Beng.; *Bhendi*, Mar.; *Huvarasi*, Kan.; *Portia*, *pursa*, Tam.

A small or moderate-sized evergreen tree of the coast forests of India and Burma, largely planted as a roadside tree in tropical regions and recognized by its large yellow flowers with purple centres, its cordate leaves, and the black turban-shaped capsules which remain long on the tree. It prefers light porous soil. It is easily raised from seed or from cuttings, and grows quickly. Cuttings of all sizes strike well, but trees raised from large cuttings are said to be short-lived and liable to decay, and it is preferable to raise plants from small cuttings put down in the nursery. It flowers more or less throughout the year, but chiefly in the cold season.

4. ERIODENDRON, DC.

Eriodendron anfractuosum, DC. White cotton tree, kapok tree.

A moderate-sized soft-wooded deciduous tree with whorled horizontal branches and digitate leaves; stems of young trees armed with conical prickles. The tree is indigenous in the Andamans, the Malay Peninsula and Archipelago, in tropical America, and possibly but doubtfully so in the west of the Indian Peninsula: it is often planted. Its fruits furnish a silk-cotton (kapok) of better quality than that of *Bombax malabaricum*. The tree can be propagated from seed or from cuttings. An article in the *Bulletin of the Imperial Institute*, vol. ix, No. 2 (1911), p. 121, describes the cultivation of the tree in Java for the sake of its silk-cotton. The seed is sown in the nursery in drills 10 to 12 in. apart, and only lightly covered with earth. The seedlings are shaded until about 5 or 6 in. high and then exposed to the sun: they are planted out when eight to twelve months old, a spacing of about 18 ft. by 18 ft. being recommended. Before transplanting it is advisable to strip off the leaves and prune the stem down to a height of 1½ to 2 ft., and also to prune down the chief roots to some extent. During the early years of the plantation other plants can be cultivated between the young trees; in Java it is customary to grow pepper in this way, but it should not be planted before the kapok trees are three or four years old. The trees begin to bear in the third or fourth year, but sometimes not till later: a large crop is never obtained until the sixth year. A large tree produces 1,000 to 1,500 fruits per annum, each of which contains about 0.7 to 1.2 grammes of dry fibre. Hence on an average a well-developed tree may be expected to produce an annual yield of ¾ to 1½ kilograms (about 1½ to 2¾ lb.) of clean fibre. In Java the tree flowers in April-May, and the fruits ripen in October-November: in India it flowers in December-January, and the fruits ripen in March-April. The fruits are collected when they are just beginning to open, by means of a long bamboo pole bearing a small hook at the upper end, and are placed in the sun until they open, when the seeds and fibre are picked out and then separated by beating or by means of a simple machine: the device described above (p. 137) for separating the seed from the floss of *Bombax malabaricum* would be suitable.

5. ADANSONIA, Linn.

Adansonia digitata, Linn. Baobab, Monkey bread tree.

A tropical African soft-wooded tree which has been introduced into India. Its growth is rapid, and it is remarkable chiefly for the enormous thickness of its trunk, which tapers upwards and divides into large limbs.

6. DURIO, Linn.

Durio zibethinus, Linn. Durian. Vern. *Duyin*, Burm.

A large handsome pyramidal evergreen tree, indigenous in the Malay Archipelago and extensively cultivated in Tenasserim. It is celebrated for its large prickly fruits, which have a most offensive odour. The cream-coloured pulp surrounding the seeds is considered by some to be a great delicacy. The seeds are large, about twelve weighing 1 lb. ; they soon lose their vitality.

7. CULLENIA,

Cullenia excelsa, Wight. Vern. *Vedupla*, Tam. ; *Karayani*, Mal.

A moderate-sized to large evergreen tree, pyramidal in shape, and somewhat resembling the durian in habit, indigenous in the Western Ghats from Coorg southwards and in Ceylon. The fruit, which is not edible like the durian, is the size of a large orange, and is densely covered with prickles ; it does not possess the offensive odour of the durian. The seeds are few, 1·3 in. long, brown, shining, with a hard testa, surrounded by a large fleshy white arillus, about 40–45 weighing 1 lb. ; they are somewhat perishable.

ORDER XI. STERCULIACEAE

This order is of considerable forest importance, furnishing besides fibre-yielding trees certain species with good timbers.

Genera 1. STERCULIA, Linn. ; 2. HERITIERA, Aiton ; 3. PTEROSPERMUM, Schreber ; 4. HELICTERES, Linn.

1. STERCULIA, Linn.

* Soft-wooded trees with timber of little value, but some of which yield useful bast fibres or gums : there are over twenty species in India, most of which are deciduous.

Species 1. *S. urens*, Roxb. ; 2. *S. villosa*, Roxb. ; 3. *S. alata*, Roxb. ; 4. *S. foetida*, Linn.

1. *Sterculia urens*, Roxb. Vern. *Gulu, kulu, gular*, Hind. ; *Karai, kandol*, Mar.

A moderate-sized to large deciduous tree with smooth greenish grey or white bark peeling in large papery exfoliations. It is characteristic of dry open forests, chiefly on stony and rocky hills, in northern and central India, the Deccan, Rajputana, and Chota Nagpur, usually associated with *Boswellia serrata* and often gregarious ; it also occurs on the west coast on rocky ground in North Kanara and the Konkan. In Burma it is found in dry upper mixed forests in hilly country. In India it is leafless from November–December till

about May, and the gaunt white stems with stiff spreading branches are a somewhat weird sight. It flowers from December to March, the panicles of flowers appearing at the ends of the leafless branches; the red follicles, covered with stinging bristles, ripen about April. The tree is useful for re-clothing bare rocky ground; it also yields a gum.

2. *Sterculia villosa*, Roxb. Vern. *Udal*, Hind.; *Sarda*, Mar.; *Shawni*, Burm.

A large deciduous tree with grey or brown bark covered with corky nodules, and branches showing large leaf-scars; it is common in deciduous forests throughout the greater part of India and Burma. It sometimes attains very large dimensions, with a straight clean bole; Mr. A. Rodger records a tree 14 ft. in girth in the Ruby Mines district of Upper Burma. In the Bengal Duars some fine specimens are to be seen in the drier types of forest on deep gravel formation near the base of the outer hills associated with *Shorea robusta*, *Lagerstroemia parviflora*, *Cedrela Toona*, *Bombax malabaricum*, *Albizia procera*, *Terminalia belerica*, *Gmelina arborea*, and other deciduous trees. The large long-stalked deeply lobed leaves fall in November–December, turning first yellow, then brown and shrivelling up, and the tree remains leafless till May or June. In January–February the clusters of drooping panicles of yellowish flowers are conspicuous at the ends of the bare branches, the five-lobed calyces, about 0.5 in. in diameter, yellow with a reddish centre, falling to the ground in quantity: the dry follicles of the previous year are often still on the tree at this time. The follicles ripen in April–May, their beautiful scarlet lining when they open giving them at first sight the appearance of flowers. The seeds germinate at the beginning of the rains, soon after falling: about 110–120 weigh 1 oz. The seeds are somewhat perishable; a sample kept for one year showed a fertility of only 6 per cent. In soil which is stiff or too damp the seedlings are apt to rot off; a light sandy soil is most favourable to their establishment. Germination is hypogeous, the cotyledons remaining within the testa and developing short petioles from between which the plumule emerges: the early leaves are three-lobed. The tree coppices well and grows very rapidly. Natural seedlings in an experimental plot near Kotdwara, United Provinces, attained a height of 15 to 20 ft. in four to five years. The bast yields a strong fibre which is much in request for rough cordage; the cortex yields a white gum.

3. *Sterculia alata*, Roxb. Syn. *S. Haynii*, Bedd. Vern. *Tula*, Beng.; *Tattele mara*, Kan.; *Ana thondi*, Mal.; *Letkók*, Burm.

A very large evergreen tree with smooth grey bark, a straight cylindrical bole, and large simple entire leaves; large trees are often buttressed at the base. It occurs in the Tista valley, Sikkim, the Duars (not common), Assam, Chittagong, Lower Burma, the Andamans, the west coast of India from North Kanara southwards, Tinnevely, and Travancore. It is found sporadically in moist situations in tropical evergreen forest, where it is one of the largest trees met with, often towering over the surrounding vegetation. The flowers appear in February–March, and the large globose woody follicles ripen in the cold season: the seeds are winged, about 2.5 in. long, some 20–30 being packed closely in each follicle. Natural seedlings and saplings are sometimes fairly numerous in the neighbourhood of seed-bearers, and are easily recognized

from their large entire ovate leaves with a cordate base and three or five nerves : they are capable of establishing themselves in the forest under fairly dense shade. The tree is much cultivated for ornament and as an avenue tree, and does well even as far north as Dehra Dun and Lahore ; it suffered severely, however, from the abnormal frost of 1905, trees about 3 ft. in girth being killed down, though they subsequently recovered from the base. The tree coppices well.

4. *Sterculia foetida*, Linn. Vern. *Jangli badam*, Hind. ; *Pinari*, Tam. ; *Letkôk, shawbyu*, Burm.

A large deciduous tree with whitish bark, long-stalked digitate leaves, and flowers with an offensive odour, appearing when the tree is leafless : the seeds are roasted and eaten. The tree is indigenous in western and southern India and Burma, and is sometimes cultivated. It is easily raised from seed, the seedlings growing rapidly and forming long taproots ; they can be transplanted during the first rains without much difficulty. The seedlings will not stand the cold of northern India.

2. HERITIERA, Aiton.

This genus contains five (or more ?) Indian species, of which two, *H. Fomes*, Buch., and *H. littoralis*, Dryander, are littoral and the others are inland species. The most important timber tree of the genus is *H. Fomes*, Buch., the *sundri* of the Sundarbans.

Species 1. *H. Fomes*, Buch. ; 2. *H. littoralis*, Dryand. ; 3. *H. Papilio*, Bedd.

1. *Heritiera Fomes*, Buch. Syn. *H. minor*, Roxb. Vern. *Sundri*, *sunder*, Beng. ; *Pinlè-kanazo, ye-kanazo*, Burm. ; *Razo*, Arakan.

A gregarious evergreen tree with buttressed stem and grey longitudinally cracked bark, moderate sized in the Sundarbans, attaining larger dimensions in Burma. In the Sundarbans trees were at one time found up to 6 ft. in girth, and even stems 7 ft. in girth have been recorded among logs obtained from this tract, but owing to heavy fellings and the difficulties experienced in controlling them, trees over 3 ft. in girth are now by no means common. A tree 8 ft. in girth was measured in 1915 in the Nangli coupe, compartment 24 of the Sundarbans. The tree grows to a height of 50 to 80 ft., according to locality. The wood is very hard, tough, and elastic, and is much in demand for boat-building, buggy-shafts, building, and other purposes.

DISTRIBUTION AND HABITAT. The Sundarbans forests of the Ganges-Brahmaputra delta in Bengal, the coasts of Chittagong, Arakan, and Burma, ascending the rivers within tidal limits. On the Arakan and Bassein coasts of Burma there are extensive *sundri* forests, which have hitherto been little worked, while in Tenasserim there are belts of *sundri* along many of the tidal creeks and round the islands, especially in the Mergui district. These littoral forests in general comprise three distinct belts, an outer fringe near the sea consisting of pure mangrove forest ; an intermediate belt of various trees mixed with mangroves, with or without *sundri* ; and an inner belt of pure or nearly pure *sundri*. In the Sundarbans the outer pure mangrove belt is absent or very limited, though *Ceriops* forms nearly pure forest on the higher ground near the sea. As illustrating the gregarious nature of the tree,

enumerations by Mr. J. D. Hamilton in eleven sample plots in *sundri* forest in Arakan showed the following average stock :

Seedlings	357 per acre.
Trees 1-2 ft. in girth	104 „
„ 2-3 ft. „	52 „
„ 3-4 ft. „	23 „
„ 4-5 ft. „	8 „
„ 5 ft. and over in girth	2.7 „

Further enumerations in the Sundarbans forests of Bengal are quoted below.

As regards climatic requirements, the *sundri* grows in regions with a warm equable climate and a fairly heavy rainfall. The following meteorological statistics refer to the principal localities in which *sundri* forests are found :

Locality.	Absolute maximum temperature. Fahr.	Absolute minimum temperature. Fahr.	Normal rainfall. in.
Sundarbans	102°	45°	63-88
Chittagong and Arakan coast .	99°-100°	45°-48°	105-210
Bassein coast	100°	55°-64°	110-117
S. Tenasserim coast	98°-100°	44°-48°	160-200 or more.

The Sundarbans forests. The famous Sundarbans tract of Bengal, in which the *sundri* is the most important species, is one of the most valuable forest estates in India ; it supplies with timber, firewood, and other produce not only the surrounding districts but also the town of Calcutta. This tract forms the southern portion of the Gangetic delta, bordering on the Bay of Bengal and extending 180 miles east to west and 80 miles north to south. The Government forests of this tract are confined to the Twenty-four Parganas and Khulna districts : the reserved forests comprise an area of 1,703 square miles, of which 594 square miles are water-channels, while the protected forests, portions of which have been disforested from time to time, at present comprise an area of 1,711 square miles. Apart from the Government forests there is an adjoining tract of forest in the Backerganj district in process of being cleared for cultivation.

The forests occupy a flat plain of recent alluvial origin formed, and still in process of formation, by the gradual deposition of silt brought down by the Ganges and Brahmaputra rivers, and intersected by a network of rivers and channels. The larger estuaries, which run in a general north to south direction, are more than a mile wide where they enter the forest and three to four miles in width where they debouch into the Bay of Bengal. These estuaries or rivers are old beds of the Ganges, which has gradually trended eastwards forming new channels, and these old beds would long since have silted up but for tidal action : their upper reaches, traversing cultivated lands, are gradually silting up, preventing fresh water from passing down them, with the result that their lower reaches are tending to become more and more salt. Apart from the main estuaries there are innumerable side channels known as *khals*, some of which (*barani khals*) lead from estuary to estuary, and others (*maru khals*) gradually branch into smaller channels until they disappear in

the forest. Many of the smaller *khals* have their origin in depressions of varying size known as *bhils*, which as a rule are not well stocked with tree growth. The *khals* are kept open by the action of the spring tides, which at high water cover the whole country to a depth of a foot or more, and in receding scour out the channels and prevent them from silting up. On cultivated lands the construction of bunds to keep out the salt water prevents this tidal action and causes the channels to silt up. During the dry season the influence of the tides is felt far up the channels, but in the rainy season tidal action is nullified by the constant stream of fresh water seawards. The *khals* are the natural highways for the extraction of forest produce, which is all brought out by boat, the tidal currents being utilized for conveying the boats in one direction or the other. The erosion which takes place along the banks of some of the larger rivers is counterbalanced by fresh deposits of alluvium in the form of low islands usually near the centre of the mouths of the estuaries: these islands or banks, locally known as *churs*, vary in composition from hard sand along the sea-face to soft mud farther inland, and frequently form barriers across the mouths of the larger rivers, especially towards the east of the Sundarbans, constituting a danger to navigation. When these banks become islands they intercept the seeds of trees and other plants carried down by water, and thus in time become covered with forest growth and merge into the forest tract as a whole.

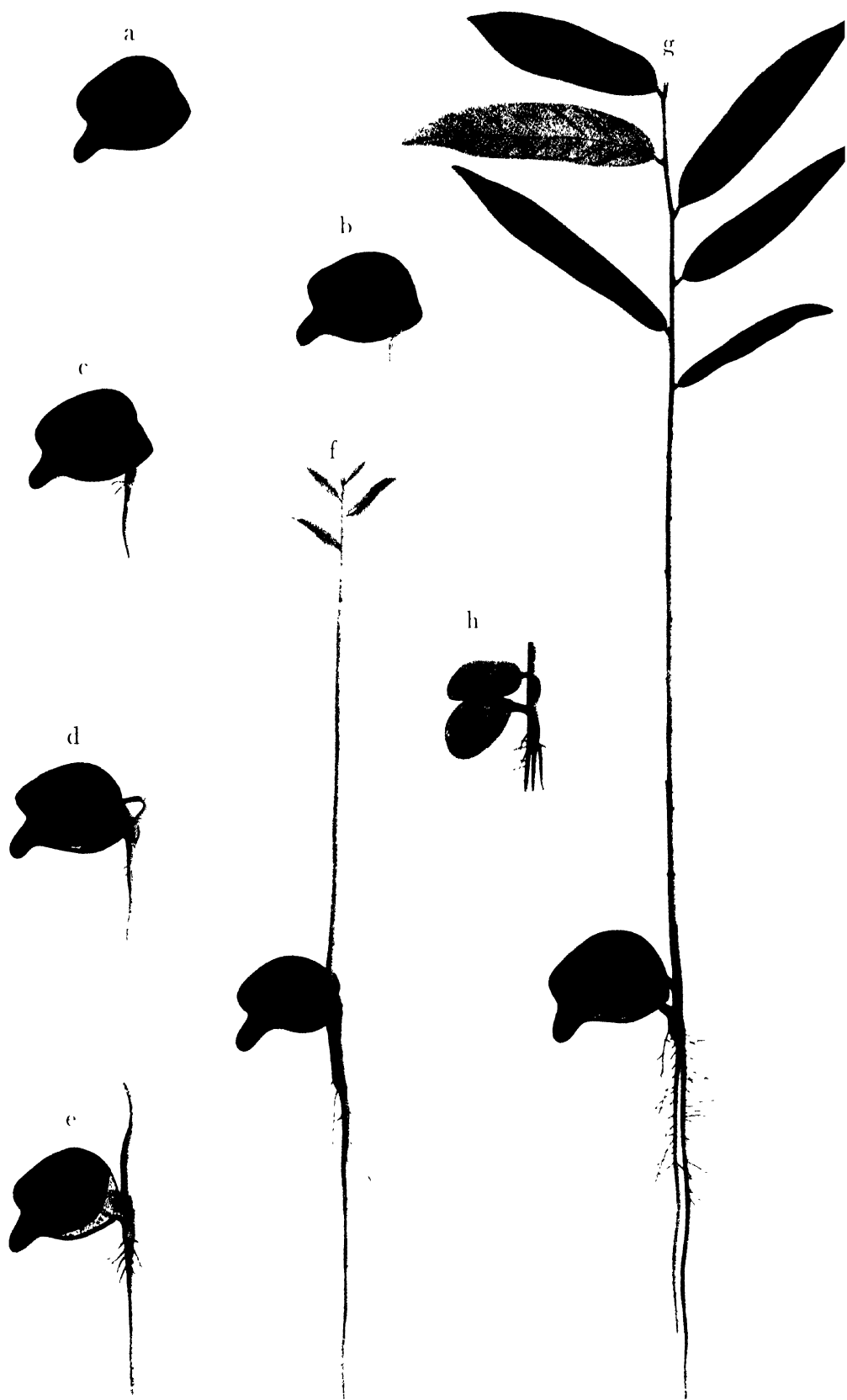
The lowest portion of the Sundarbans lies to the west of the Pussur river in the northern part of the forests, where there are many low-lying *bhil* areas. Some of the strips near the sea never become inundated, even at spring tides, and it is noteworthy that during spring tides deer and other animals congregate on the higher ground towards the sea-face in order to escape the floods. The lower portions of the Sundarbans are flooded at every high tide, fresh deposits being thus accumulated by slow degrees until the ground gets above the reach of ordinary tides and is covered only by spring tides, which inundate the whole of the Sundarbans forest tract except the highest ground near the sea. The vegetation of the Sundarbans comprises numerous species of trees, of which the principal, besides *sundri*, are *Excaecaria Agallocha*, *Sonneratia apetala*, *S. acida*, *Carapa moluccensis*, *C. obovata*, *Amoora cucullata*, *Aegiceras majus*, *Cynometra ramiiflora*, *Avicennia officinalis*, and the mangroves *Ceriops Candolleana*, *C. Roxburghiana*, *Kandelia Rheedii*, *Rhizophora mucronata*, and *Bruguiera gymnorhiza*. *Pongamia glabra* is found along sand-hills near the sea, and mango, *Diospyros Embryopteris*, and a few other trees occur on former village sites. On newly formed islands, flooded by every tide, *Sonneratia* usually springs up first, followed by *Avicennia* and the palm *Nipa fruticans*. As the ground rises other trees make their appearance, the most prevalent, though one of the later species to appear, being *Excaecaria Agallocha*. As the level rises by accretion, and the land is only occasionally flooded by the tide, the *sundri* makes its appearance. It is not uncommon to find *sundri* springing up under large dying *Sonneratia* trees, the suckers of which have become silted up. In the western or lower half of the Sundarbans there is little or no *sundri*. In the eastern half it is scarce near the sea-face except in the most easterly portions, but on proceeding inland it increases in quantity until pure or nearly pure *sundri* forests are met with. On the existence of two separate

types or qualities of *sundri* forest Mr. Trafford¹ remarks : ' Observation of sample plots and measurements of trees have brought to light the existence of two types of *sundri* forest which may be described as (a) the salt-water type and (b) the fresh-water type. The former is found in the area near the sea-face and on the high ground which forms the banks of all large and medium-sized *khals* throughout the forests. The growth of the salt-water type is extremely slow, and the average figures yielded by one sample plot show that it is only $\frac{1}{8}$ of a foot per annum. So universal is the presence of this type along the banks of streams navigable by steam launches, that any one traversing the forest without going into the smaller *khals* would receive the impression that there are few or no good *sundri* trees in the Sundarbans. The fresh-water type of forest predominates at a distance of from one to three hundred yards from the edge of all *khals*. This forest consists of straight tolerably tall stems of from one to two and a half feet in girth, growing fairly compactly with little or no undergrowth, and in places containing over three hundred trees per acre.' The growth of the *sundri* is best where the level of the ground is intermediate between the high strip along the *khals* and the low *bhil* areas farthest away from them; the quality is usually also good towards the sources of the smaller *khals*. The proportion of *sundri* in the crop varies greatly, linear valuation surveys showing a variation of 1 to 240 *sundri* trees $1\frac{1}{2}$ ft. in girth and over per acre according to the degree to which the *sundri* is mixed with other species or forms more or less pure crops. Enumerations by Mr. A. L. Home, recorded in the Bengal Forest Report for 1873-4, showed an average per acre of 2,487 seedlings and saplings under 3 ft. in girth and 182 trees 3 ft. in girth and over; these figures must refer to pure *sundri* crops, and not to a general average such as is obtained from linear valuation surveys traversing various types of forest. On the *bhils* or depressions the *sundri* trees, where present, tend to deteriorate rapidly and to die off.

In dense forest of *sundri* undergrowth is practically absent, but in certain portions of the area, particularly in low-lying places, there is an undergrowth of varying density, sometimes thick and almost impenetrable, of which the principal species are *Nipa fruticans* (vern. *golpatta*), a small palm much in request for thatching, and common along watercourses, in *bhils*, and other open places; *Phoenix paludosa* (vern. *hantal*), a palm forming impenetrable prickly masses usually on the higher ground where the forest has been opened out; *Hibiscus tiliaceus* (vern. *bhola*), a climber growing to a height of about 10 ft. and forming dense matted thickets; *Pandanus odoratissimus* (vern. *kewa*), forming a troublesome prickly undergrowth under fairly dense shade; *Acanthus ilicifolius* (vern. *hargoza*), common near the sea-face and forming dense prickly masses; *Derris sinuata* (vern. *sundrilota*), a common creeper, usually in the neighbourhood of *khals*; and *Acrostichum aureum* (vern. *udoban*), a large-leaved fern forming a very common undergrowth, often to the exclusion of almost all other plants; areas covered with this fern are favourite haunts of the man-eating tigers which infest the Sundarbans.

Fig. 64 gives an idea of a *sundri* pole crop in the Sundarbans which has just been thinned.

¹ Working Plan for the Forests of the Sundarbans Division, 1911.



SPREAD AND GERMINATION OF SEED. The fruit carpels (Fig. 66, a), 1.5–2 in. long by 1–1.5 in. broad, 12–15 weighing 1 oz., ripen in July–August and fall to the ground, or in the case of trees growing near the banks of water-channels they fall into the water, and being buoyant are borne along in quantities on the surface by the tidal currents until stranded: in the spring tides of August the masses of seeds on the surface of the water have the appearance of immense rafts, so closely do they float together. The seed is liable to the attacks of an insect which may destroy much of the early part of the crop. Germination (Fig. 66, b–e), which is hypogeous, takes place very soon after the carpels fall. The thick fleshy cotyledons remain within the fibrous wall of the carpel; the stout radicle appears first, the petioles of the cotyledons meanwhile elongating so as to enable the plumule to emerge; the latter soon appears, the young shoot elongating and arching until free, when it straightens.

THE SEEDLING (Fig. 66).

Roots: primary root moderately long, thick, terete, tapering: lateral roots numerous, long, fibrous, distributed down the main root but most numerous on the upper part. *Hypocotyl* distinct from the root, 0.4–0.5 in. long by 0.2 in. or more in diameter, pink to light brown, subterranean. *Cotyledons* subterranean: petiole 0.4–0.5 in. long by 0.1–0.15 in. in diameter, terete or slightly compressed, woolly tomentose, curved to one side of stem: lamina 1.1–1.3 in. in length and breadth, thick, fleshy, orbicular, apex rounded, base sagittate, pinkish white, glabrous, outer surface convex, smooth inner surface concave or irregularly undulating. *Stem* erect, terete, light greenish brown, covered with silvery scales and lenticels, leafless for several nodes and for a length of 7–18 in. or more; internodes chiefly 0.5–1.5 in. long, the earlier ones often longer, up to 6 in. or more. *Leaves* simple, alternate, the first few abortive. *Stipules* 0.1–0.15 in. long, acuminate, caducous. *Petiole* 0.1–0.2 in. long; stellate pubescent. *Lamina* 2.5–6 in. by 0.4–1 in., oblong lanceolate, acute or acuminate, entire, coriaceous, upper side green, glabrous or with scattered silvery scales, lower side covered with silvery scales.

The early development of the seedling is very rapid. Within a month the stem may reach a height of 18 in. or more, and the stout taproot a length of 7 or 8 in., with a number of fairly long lateral roots. This early development enables the seedling to obtain a footing in spite of floods, and it is interesting to note that there may be a considerable length of bare stem with only scaly abortive leaves, the normal leaves being borne in the upper part of the stem where they are likely to be above the level of the water. During the rapid development of the leafless stem the plant receives its food from the starchy cotyledons. A similar early development is noticeable in the case of *Carapa moluccensis*, and it is possible that a further study of the development of seedlings of littoral species may reveal other instances of the same kind.

SILVICULTURAL CHARACTERS. The *sundri* is a moderate light-demander, enduring more shade in youth than it does later. The general habits of the tree have already been indicated in the description of the Sundarbans forests above, and in particular it may be noted that the tree avoids the lowest and newest land subjected to submergence by every high tide, and seeks the higher ground which is only flooded by brackish water for a few days twice a month. It does not flourish on the highest ground, which is often very saline, but grows best on land intermediate in level between the highest and the lowest.

It is a freshwater rather than a salt-water species, and avoids areas which are highly saline or are liable to flooding by pure salt water. On the more saline areas the trees tend to deteriorate and die, or while still of comparatively small dimensions to reach a stage, locally known as *pukka*, where further growth practically ceases. Mr. Trafford points out that this want of vigour may be traced to the deleterious effect of the salt in the soil, which is more pronounced on high land than on land exposed to frequent inundation by the tide. During the dry season the evaporation of water from high ground causes the salt held in solution to be deposited at or near the surface of the soil, which thus becomes saturated with salt. This theory is borne out by the fact that the growth of trees generally, and of *sundri* in particular, is more rapid towards the east of the Sundarbans, where fresh water persists for a good part of the year, than in the west, where the water-channels remain more or less salt throughout the year. Probably, however, the mere silting up of the root-system, preventing soil-aeration, accounts in part for the deterioration or death of the trees. The root-system of the *sundri* is decidedly abnormal. The roots do not penetrate very deep, but spread laterally not far below the surface, sending up numerous blind suckers or pneumatophores (locally known as *shoolas*) from a few inches to over a foot above the surface of the ground; these suckers, which are believed to be breathing organs, resemble inverted tent-pegs and cover the ground in the neighbourhood of the trees, making progression difficult (see Fig. 64). The coppicing power of the *sundri* varies considerably. So far as observations go, coppice reproduction is poor in places where the trees show the best development and most vigorous growth, as in the freshwater type of forest, whereas on the saline soil of the salt-water type and on drier ground, where the growth and development of the trees is poor, coppice growth is remarkably vigorous; possibly this may be due in part to the fact that on drier ground less energy is spent by the trees in producing suckers. For successful coppice growth abundance of light is required. The *sundri* pollards well. Fire, frost, and grazing do not occur in the Sundarbans forests. Severe damage is done periodically at fairly long intervals by cyclones, which uproot the trees, break the tops off, or tear off the branches. The last severe cyclone occurred in October 1909 and caused immense damage: the direction in which the trees were thrown showed that at the height of the storm the wind blew from east to west.

NATURAL REPRODUCTION. The seeds, as already noted, ripen and fall in the rainy season and are transported in large quantities by water action. The forces operating on its dissemination are the strong floods of river water and local rain seawards, the spring tides which occur at this season, and the monsoon winds blowing from the south-west. The last factor is evidently an important one, since seedlings are often found in greatest quantity on the north and east banks of the larger rivers and water-channels where they have been washed by the waves formed by the monsoon winds. Where seed has been stranded in quantity seedlings appear in enormous numbers, forming thickets of great density.

Experience has shown that judicious thinnings greatly stimulate the establishment of seedlings. Regeneration, however, appears to be more successful under moderate cover than where the canopy is too heavily opened

out, and hence the thinnings should not be too drastic ; heavy cover, on the other hand, prevents the establishment of natural regeneration. Where clearings are made in the *sundri* tracts regeneration is a very uncertain matter, since unless the direction of the flood water is favourable the seed has no means of being conveyed to the cleared areas ; in any case it is by no means certain that seedlings will be able to establish themselves on open blanks.

SILVICULTURAL TREATMENT. The treatment at present applied to the *sundri* tracts of the Sundarbans under the working plan of 1911 is based on the beneficial effects of thinnings on the development of the crop and on natural reproduction, the other factors taken into consideration being the large areas to be dealt with, the difficulty of supervising felling, and the deterioration of the forests as a result of the earlier working in vogue some years previously. The treatment now in force is provisional, and consists of improvement fellings by area combined with thinnings under a felling cycle of forty years, the exploitable girth for sound *sundri* being fixed at 3½ ft. In the salt-water type, where the growth is slow, one felling in forty years is considered sufficient, but in the freshwater type, where the growth is considerably faster, a thinning will precede the main felling at as long an interval as is practicable—sixteen years being fixed in the present working plan—while subsidiary thinnings will be executed as required in the more accessible areas.

The value of judicious thinnings in increasing the rate of growth of the *sundri* has been fully demonstrated in the Sundarbans : if they are carried out too drastically, however, the trees tend to produce epicormic branches. In the cyclone of 1909 thinned areas in exposed situations on the banks of watercourses suffered severely, whereas many heavily thinned areas sheltered by forest on the east escaped with little or no damage : the state of the ground, however, appeared to have more effect on the degree of damage than any other factor, the number of trees blown down being greater on the softer and wetter ground than on the harder and drier ground.

RATE OF GROWTH. Measurements extending over sixteen years in four sample plots in the Sundarbans show a mean annual girth increment of 0·5 in. in the best plot, of the freshwater type, as against 0·21 in. in the worst plot, of the salt-water type. This indicates that the growth is decidedly slow, though measurements in adjacent thinned and unthinned sample plots prove that thinnings result in a considerable acceleration of girth increment. Statistics regarding the rate of growth of coppice-shoots are not available : Mr. Trafford notes that coppice-shoots four years old in the Slanekhali block of the Sundarbans had a maximum height of 8 ft.

2. *Heritiera littoralis*, Dryand. Looking-glass tree. Vern. *Pinlè-kanazo*, Burm. ; *Mawtda*, And. ; *Chandmara*, Kan. ; *Sundrichand*, Mar. ; *Chomuntiri*, Tam.

A moderate-sized gregarious evergreen tree with grey longitudinally furrowed bark, found in the littoral forests of Burma, the Andamans, the Indian Peninsula, and Ceylon. Although commonly found along the sea-coast it succeeds fairly well in Ceylon up to about 1,500 ft. elevation. In the Andamans it grows in the littoral zone down to the level of high tide, and in places where the mangrove forests are absent, and also to some extent on the flat muddy ground close to the mangrove swamps. Its chief companions are

Cynometra ramiflora, *Erythrina indica*, *Mimusops littoralis*, *Hibiscus tiliaceus*, *Thespesia populnea*, *Terminalia Catappa*, *Carapa moluccensis*, and *Calophyllum Inophyllum*. Talbot says the roots do not apparently develop blind root-suckers like the Sundarbans species.

3. *Heritiera Papilio*, Bedd. (possibly including *H. acuminata*, Wall., a tree of the Khasi hills).

A very large tree of the evergreen forests of Tinnevely and Tranvancore between 2,000 and 4,000 ft.; its most important associates are *Mesua ferrea*, *Vitex altissima*, *Litsaea zeylanica*, and *Bischofia javanica*.

3. PTEROSPERMUM, Schreber.

Several trees of this genus are planted for ornament, and are interesting owing to the variety in the form of their leaves, their showy usually white flowers, five-valved woody capsules, and winged seeds; the capsules sometimes ripen at the time the tree is in flower, taking a year to mature, and usually persist for some time after ripening. Some species (e. g. *P. acerifolium*, Willd., and *P. semisagittatum*, Ham.) are known to produce root-suckers freely; this may possibly be a general characteristic of the genus.

Pterospermum acerifolium, Willd. Vern. *Mayeng*, Jaunsar; *Hati-paila*, Nep.; *Kanak-champa*, Beng.; *Taung petwin*, Burm.

A large handsome evergreen tree with thin grey smooth bark and large round somewhat variable deeply cordate or peltate leaves, dark green above and white tomentose beneath. Wood moderately hard, reddish, of good quality, suitable for carpentry, and sometimes used for planking.

DISTRIBUTION AND HABITAT. The sub-Himalayan tract and outer Himalayan valleys and hills up to 4,000 ft., Bengal, Chittagong, Khasi hills, Manipur, Burma, North Kanara. Often planted for ornament. The tree is found wild in a variety of situations. In the Dehra Dun valley it is common in swamp forests associated with *Trewia nudiflora*, *Diospyros Embryopteris*, *Eugenia Jambolana*, *Cedrela Toona*, *Ficus glomerata*, *Putranjiva Roxburghii*, *Phoebe lanceolata*, *Machilus Gamblei*, and sometimes *Bischofia javanica* and *Carallia lucida*. In the outer Himalaya it is found along river-banks, but also ascends the hill-sides, where it is sometimes seen even in fairly dry situations, though in such places the subsoil is moist, overlying water-bearing rocks. In Burma it is common along streams in tropical and moist upper mixed forests. Talbot says it is found on the southern *ghats* of North Kanara in evergreen rain-forests, and that it is abundant in the Devimone forests. In its natural habitat the absolute maximum shade temperature varies from 95° to 110° F., the absolute minimum from 30° to 60° F., and the normal rainfall from 55 to 150 in. or more.

FLOWERING AND FRUITING. The large scented white flowers appear from March to June, and the capsules ripen a year later, opening about the time the tree is in flower. The capsules are 4-6 in. long, dark brown, tomentose woody, five-valved. The seeds (Fig. 67, a) are brown, compressed, with large membranous terminal wings, the whole being 1.3-2 in. long: they are thus adapted for distribution by wind. The fertility of the seed is usually good and it retains its vitality well for one year: tests made with samples of seed

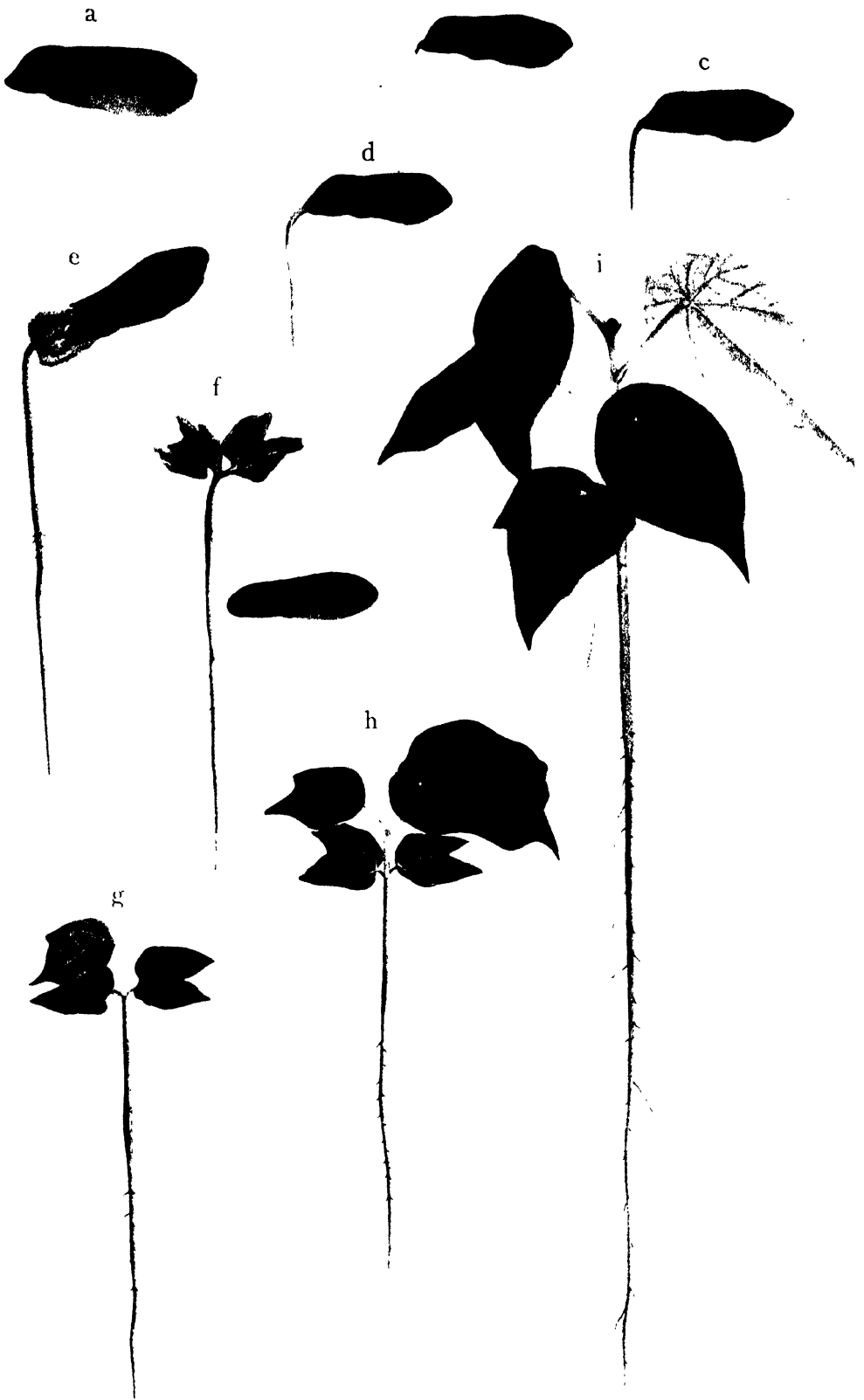


FIG. 67. *Pterospermum acerifolium*—SEEDLING X

kept for a year showed a fertility of 70 per cent., while seed kept for two years had a fertility of only 10 per cent.

GERMINATION (Fig. 67, *b-f*). Epigeous. The radicle emerges from the end of the seed opposite the wing and descends. The hypocotyl elongates, sometimes with slight arching, and carries above ground the cotyledons, which are much crumpled before expansion. The testa is either left on or under the ground or is carried up over the cotyledons, falling with their expansion.

THE SEEDLING (Fig. 67).

Roots: primary root long, terete, tapering, greyish brown, woody: lateral roots numerous, fine, fibrous, distributed down main root. **Hypocotyl** distinct from the root, 1.5-1.8 in. long, terete or slightly compressed, fusiform, white turning green, tomentose. **Cotyledons**: petiole 0.15-0.2 in. long, tomentose: lamina 0.7-0.8 in. by 0.6-0.9 in., foliaceous, sub-orbicular, entire or bifid, palmately 5-veined from the base. **Stem** erect, terete, white tomentose; internodes 0.1-0.5 in. long. **Leaves** simple, alternate. Stipules 0.1 in. long, linear. Petiole (early leaves) 0.5-1.2 in. long, tomentose. Lamina (early leaves) 1.8-3 in. by 1-2 in., ovate acuminate, peltate, entire or irregularly or obscurely toothed, dark green and glabrous or stellate pubescent above, white tomentose beneath, radiately 7- or 8-veined.

The development of the seedling during the first season is slow, a maximum height of 6 in. with a taproot up to 8 or 10 in. long being as a rule attained even if regular watering and weeding are carried out. During the second season, however, the growth under favourable conditions is very rapid, nursery-raised plants which have not been transplanted attaining a height of as much as 4½ ft. and producing large leaves. By the end of the third season the height of such plants may increase to as much as 13 ft. Transplanting appears to check the growth, transplanted seedlings often showing very little stem development in the second season, though the taproot may attain a length of as much as 2 ft. The same applies to seedlings which remain unweeded and unwatered, these often being not more than 3 in. high at the end of the second season, if they are fortunate enough to survive as long. The growth of seedlings ceases in the cold season (northern India). Seedlings are decidedly frost-hardy, but are sensitive to drought.

SILVICULTURAL CHARACTERS. The tree is a moderate shade-bearer. It is fairly frost-hardy, but in the abnormal frost of 1905 in northern India it was slightly to badly damaged. The tree coppices well and produces root-suckers in abundance.

NATURAL REPRODUCTION. Experiments at Dehra Dun have shown that under natural conditions the seeds germinate early in the first rainy season after they fall, and that a considerable amount of soil moisture is necessary for the establishment of the seedlings, which are sensitive to drought and die off if they come up in situations exposed to a hot desiccating sun. A good deal of the natural regeneration seen in the forest consists of root-suckers.

ARTIFICIAL REPRODUCTION. Experiments at Dehra Dun show that direct sowings kept weeded and watered produce the best results, the growth after the first season being very rapid. The tree is worth cultivating as an accessory species in irrigated plantations, by means of weeded line sowings. To obtain transplants the seed should be sown in drills in nursery beds in April or May, the beds being kept well watered and weeded. The seedlings can be

transplanted without much difficulty during the first rains, in July or August, when they are about 3 in. high : transplanting in the second rains is more difficult and requires special care to prevent the stems dying down. In either case the growth of the plants is checked by transplanting, and the development for the first year or two is poor compared with that attained by direct sowings properly tended.

RATE OF GROWTH. After the seedling has established itself and commenced to shoot up growth is rapid. A height-growth of 6 ft. per annum has been attained by saplings in weeded and irrigated sowings at Dehra Dun.

4. HELICTERES, Linn.

Helicteres Isora, Linn. Vern. *Maror-phal*, Hind.

A large shrub with leaves resembling those of the hazel, common and often gregarious in many parts of India. In northern India the red flowers appear chiefly in July–August, and the fruits ripen in December–January ; the latter consist of spirally twisted carpels which untwine and split on ripening, the small seeds thus escaping. The shrub coppices very well, shooting up rapidly again even if cut or burnt back annually ; in some places, as in parts of the Siwalik tract, it becomes invasive, forming a dense almost impenetrable growth to the exclusion of other species. It yields a good fibre.

ORDER XII. TILIACEAE

This order contains a few timber trees of some importance and many accessory forest species.

Genera 1. PENTACE, Hassk. ; 2. BERRYA, Roxb. ; 3. GREWIA, Linn. ; 4. ECHINOCARPUS, Blume.

1. PENTACE, Hassk.

Pentace burmanica, Kurz. Vern. *Thitka*, Burm.

A large evergreen tree of the tropical forests of Burma, usually in hilly country. Wood light red, moderately hard, somewhat resembling mahogany in texture and used for boat-building and carpentry. According to Gamble the growth is rapid, 3 to 4 rings per inch of radius representing a mean annual girth increment of 1.6 to 2.1 in.

2. BERRYA, Roxb.

Berrya Ammonilla, Roxb. Syn. *B. mollis*, Wall. Trincomali-wood. Vern. *Petwun*, Burm.

A large deciduous tree with smooth pale thin bark, commonly attaining a height of 60–80 ft. and a girth of 6 ft. The leaves are broadly cordate. The wood is strong, elastic, and durable, and is used for building, shafts, carriage manufacture, agricultural implements, and other purposes ; in Madras it is used for boat-building.

DISTRIBUTION AND HABITAT. Throughout Burma, in suitable localities, Ceylon, Little Coco Island (Prain). Often planted in southern India. In Burma it is found scattered in upper mixed deciduous forests, chiefly of the drier type, associated with teak, *Terminalia tomentosa*, *Xylia dolabriformis*,

Dalbergia cultrata, *Homalium tomentosum*, and various other trees. It occurs to some extent in *indaing* (dry dipterocarp) forest associated with *Dipterocarpus tuberculatus*, *Pentacme suavis*, and *Shorea obtusa*. It also extends into the lower mixed deciduous forests of the plains, associated with teak, *Terminalia tomentosa*, *Lagerstroemia Flos-Reginae*, *Adina cordifolia*, *Stephegyne diversifolia*, *Adina sessilifolia*, *Terminalia belerica*, *Odina Wodier*, and other species. The tree is not gregarious, but occurs scattered in greater or less abundance. Enumerations in 1903-4 in the plains forests of the Tharrawaddy district, Burma, showed the average number of trees 3 ft. in girth and over per 100 acres to be 69 in the Satpôk reserve, 4 in the Sitkwin reserve, and 57 in the Thindawyo reserve; the total area enumerated was 20 square miles. These forests are on flat land, the soil being a rich alluvial loam with occasional pans of clay, where the tree-growth is poorer than elsewhere.

In its natural habitat in Burma the absolute maximum shade temperature varies from 100° to 110° F., the absolute minimum from 40° to 60° F., and the normal rainfall from 35 to 120 in. or more.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The tree is leafless for a time in the hot season. The panicles of white flowers appear in the cold season and the capsules ripen in the hot season. The seeds are ovoid or sub-angular, 0.2-0.25 in. long, light brown, with a hard testa and a thin albumen.

GERMINATION. Epigeous. The testa splits, and the radicle emerges and descends. The hypocotyl elongates, raising the cotyledons above ground: the testa and albumen are usually carried up over the cotyledons, falling with their expansion.

THE SEEDLING.

Roots: primary root moderately long, tapering: lateral roots numerous, fibrous, distributed down main root. *Hypocotyl* distinct from root, 1.6-2 in. long, tapering upwards, green, pubescent. *Cotyledons*: petiole 0.15-0.2 in. long, compressed laterally, pubescent: lamina 0.6-0.9 in. diameter, foliaceous, orbicular, entire, green, glabrescent, 5-veined from the base, the three central veins more prominent than the two lateral ones. *Stem* erect, terete or slightly compressed, tomentose. *Leaves*, first pair opposite, subsequent leaves alternate. Petiole 0.3-1 in. long, tomentose. Lamina 1-2 in. by 0.8-1.5 in., cordate, obtuse or acute, serrate, puberulous, 5-veined from the base.

The growth of the seedling is comparatively slow, a height of 3 to 9 in. being attained in the first season. In dry places the seedlings may die back for some years, showing little increase in height during the period. Seedlings raised at Dehra Dun have been found to be very subject to insect attacks, to which they succumb in their early stages.

SILVICULTURAL CHARACTERS. The silvicultural characters of the tree have not been studied in any detail. It is known to coppice and to produce root-suckers freely, particularly when felled.

NATURAL REPRODUCTION. The conditions which favour natural reproduction have not been sufficiently studied. Germination takes place early in the rains not long after the fall of the seed. Ordinarily the tree regenerates well, provided the canopy is open, as in the plains forests of the Tharrawaddy district, where in heavily felled areas there are numerous saplings. Mr. Walsh notes that in the Ruby Mines district the tree has difficulty in establishing

itself, seedlings, or possibly root-suckers, being plentiful round each tree, but saplings and poles being scarce. In Burma natural reproduction is sometimes plentiful in abandoned *taungyas*. In 1914-15 reproduction is reported to have sprung up freely in the Yetkanzin reserve, North Toungoo, in a bamboo-flowered area, which had been fire-protected for many years and then burnt after the flowering of the bamboo.

3. GREWIA, Linn.

This genus is a large one, containing over thirty species, chiefly shrubs and climbers, with some small to moderate-sized trees. Some species are characteristic of dry or arid regions, for example *G. populifolia*, Vahl, a shrub; *G. salvifolia*, Heyne, a shrub or small tree; and *G. flavescens*, Juss., a large straggling shrub. *G. sapida*, Roxb., is a curious undershrub common on the grassy plains of the sub-Himalayan tract, ascending to 3,000 ft.; also found in Chota Nagpur and in Upper Burma. It has a woody root-stock from which new shoots are sent up each year after the old stems have been burnt back by the annual fires: the yellow flowers appear on the new shoots in the hot season, and the fruits ripen at the beginning of the following cold season. Some species of *Grewia* have strong elastic wood, used for shafts, shoulder-poles, bows, and other purposes for which elasticity is required. They coppice well, some species producing shoots of great vigour: many, possibly all, produce root-suckers. The fruits of several species are edible.

For a botanical examination of the Indian species of *Grewia* of forest importance see Hole in *Indian Forester*, xliii, 312.

Species 1. *G. oppositifolia*, Roxb.; 2. *G. laevigata*, Vahl; 3. *G. Hainesiana*, Hole; 4. *G. elastica*, Royle; 5. *G. tiliaefolia*, Vahl; 6. *G. Microcos*, Linn.

1. *Grewia oppositifolia*, Roxb. Vern. *Dhaman*, *biul*, *bhimal*, north-west Himalaya.

A moderate-sized deciduous tree with a short straight trunk and smooth grey bark, common on the outer hills of the western Himalaya and much planted near villages, where it is heavily lopped for cattle fodder: the bark is much used for making ropes. The tree is easily propagated from cuttings or from seed, and is hardy, growing on almost any situation in the outer hills. It is leafless for a short time in March-April. It flowers from March to June, sometimes at other seasons, and the fruits ripen from October to December. The edible drupe is one- to four-lobed, black when ripe. The growth, according to Gamble, is 7 rings per inch of radius, representing a mean annual girth increment of 0.9 in.

2. *Grewia laevigata*, Vahl.

A small tree with dark grey bark and long pointed glabrescent three-nerved leaves, found usually in shady places and ravines in the outer Himalaya, in Assam, Burma, and parts of the Indian Peninsula. It flowers from June to October and fruits in the cold and hot seasons.

3. *Grewia Hainesiana*, Hole. Vern. *Phalsa*, *dhaman*, Hind.

A small tree, wild in the sub-Himalayan tract, Siwalik hills, Satpuras, and elsewhere, and cultivated for its edible fruit, propagation being best done by layering.

4. *Grewia elastica*, Royle. Syn. *G. vestita*, Wall. (*G. vestita* may be considered to be a variety of *G. elastica*.) Vern. *Dhaman*, *phalwa*, Hind.

A moderate-sized tree with grey bark, that of branches and young plants with large white blotches; leaves obliquely ovate acuminate, usually much longer than broad. This tree is found chiefly in the sub-Himalayan tract, where it is very common in sal forests, also in Bengal and central India. The wood is tough and elastic, and is used for shoulder-poles, bows, and similar purposes. It is fairly frost-hardy, and in the abnormal drought of 1907-8 in Oudh it was found to be a decidedly drought-hardy species. It coppices freely, and the coppice-shoots are of rapid growth. Measurements recorded by Mr. A. F. Broun in the Dehra Dun forests in 1886 show the following measurements of coppice-shoots of *dhaman* as compared with sal in the same coupes:

Grewia elastica: rate of growth of coppice, Dehra Dun.

Age. years.	Mean height.		Mean girth.	
	<i>Grewia</i> . ft. in.	Sal. ft. in.	<i>Grewia</i> . in.	Sal. in.
8	25 0	13 2	12	7.1
8	16 11	16 2	6.2	8.3
9	19 2	16 0	8.4	8.6
9	16 10	13 5	10.1	8.7
10	14 4	17 6	8.8	9.9
10	16 3	11 10	9.4	5.9

Measurements made in 1910 by Mr. C. M. McCrie in coppice coupes at Ramgarh, Gorakhpur, United Provinces, gave the following results in the case of *dhaman* as compared with sal:

Grewia elastica: rate of growth of coppice, Gorakhpur.

Age, years.	Mean height.		Mean girth.	
	<i>Grewia</i> . ft.	Sal. ft.	<i>Grewia</i> . in.	Sal. in.
2	5.2	3	1.4	—
4	9.1	7	2.4	2.0
6	11.5	10.3	3.2	2.9
8	13.6	13	3.8	3.8
10	15.2	15.3	4.3	4.8
12	16.6	17.5	4.7	5.8
14	17.5	19.2	5.0	6.7
16	18.1	20.9	5.3	7.5

Measurements taken for twelve years in the Malowala high forest sample plot on the south of the Siwaliks showed the following mean annual girth increments:

Girth class.	Mean annual girth increment.	Number of measure- ments.
. in.	in.	
0-12	0.50	8
12-24	0.28	10
24-36	0.73	1
36-48	0.52	2

Gamble's specimens showed 5 to 7 rings per inch of radius, corresponding to a mean annual girth increment of 0.9 to 1.26 in.

5. *Grewia tiliaefolia*, Vahl. Vern. *Dhaman*, *phalsa*, Hind.

A moderate-sized tree with large oblique leaves, common in Chota Nagpur,

central and southern India. The wood is tough and elastic and is used for shafts, shoulder-poles, and similar purposes. According to Gamble, the growth is about 6 rings per inch of radius, corresponding to a mean annual girth increment of about 1 in. The growth of young coppice-shoots is very rapid. Mr. Gass records measurements in coppice two years old in Madras, in which the height varied from 8 to 15 ft. and the girth from 2 to 7 in., the number of shoots per stool varying from 2 to 12. One-year-old coppice-shoots measured in the Bhandara division, Central Provinces, in 1912-13 had an average height of 8 ft. 2 in.

6. *Grewia Microcos*, Linn. Vern. *Myatya*, Burm.

A moderate-sized tree, sometimes only a shrub, common in Burma often as an undergrowth species, and also found in the Western Ghats, Assam, and Chittagong. It coppices vigorously, an average of 9 shoots per stool being counted in coppice coupes in the Rangoon plains forests. The leaves are much used for cheroot-wrappers in Burma.

4. *ECHINOCARPUS*, Blume.

Echinocarpus dasycarpus, Benth. Vern. *Gobria*, *gobre*, Nep.

A large handsome evergreen tree of the eastern Himalaya at 5,000-7,000 ft. Bark greyish brown, rough; wood soft, used for tea-boxes and planking in the Darjeeling neighbourhood. The tree, which is much buttressed, occurs in the middle hill forests of Darjeeling associated with a large number of species, of which the more important are *Quercus lamellosa*, *Q. lineata*, *Q. pachyphylla*, *Castanopsis Hystrix*, *Michelia excelsa*, *Bucklandia populnea*, with laurels, maples, &c. Mr. Manson (Darjeeling working plan, 1893) says it is most common on southern and western aspects, but is also found thriving on slopes facing north-west; it seeds freely, but the seedlings, which have large leafy cotyledons, are rather delicate when very young and require shelter. He adds that the tree comes up well in a sparse growth of weeds on new clearings. Mr. J. W. A. Grieve (Darjeeling working plan, 1912) notes that reproduction is very poor. The rate of growth is given in the working plan at 8-10 rings per inch of radius, corresponding to a mean annual girth increment of 0.63 to 0.78 in.

ORDER XIII. RUTACEAE

This order does not contain any trees of very great importance from a forest point of view, though it includes certain widely cultivated fruit trees, particularly of the genus *Citrus*. As pointed out by Gamble, several species have hard even-grained compact woods well worth trial as substitutes for boxwood. The order contains various shrubs or small trees, often highly aromatic, which are of some importance as species of the undergrowth; of these may be mentioned *Toddalia aculeata*, Pers., a large scandent prickly shrub of the outer Himalaya, Assam, Western Ghats, and Burma; *Skimmia Laureola*, Sieb. and Zucc., a very aromatic undershrub sometimes forming a dense soil-covering in the fir forests of the Himalaya; *Glycosmis pentaphylla*, Correa, a common undergrowth species, often forming a soil-covering in mango topes on the plains of India; *Murraya exotica*, Linn., a handsome shade-bearing



FIG. 68. *Aegle Marmelos*, Dehra Dun, United Provinces.

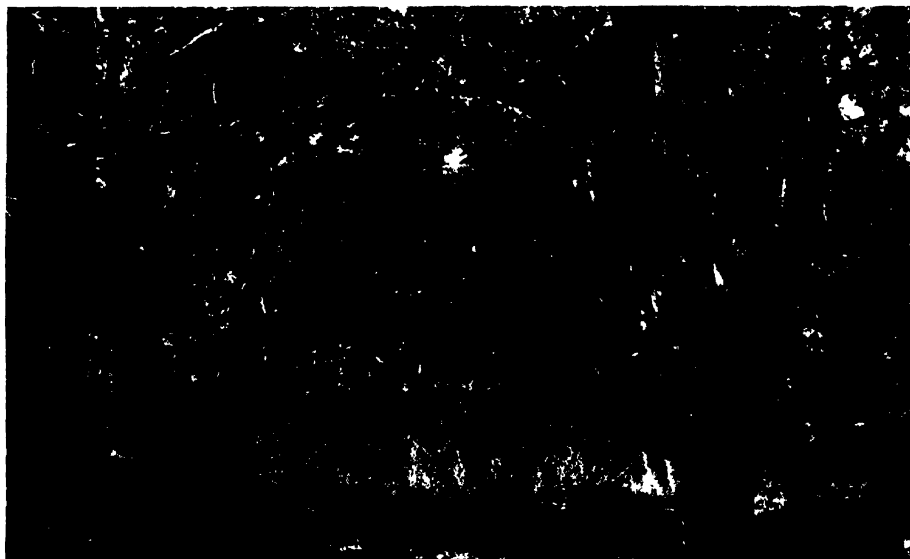


FIG. 69. *Aegle Marmelos* growing gregariously on stiff clay soil,
Bahraich, United Provinces.



evergreen shrub or small tree with red berries, found in many parts of India and Burma in shady ravines, and often cultivated for ornament; *M. Koenigii*, Spr., an aromatic shrub or small tree fairly widely distributed in India and extending into Burma, sometimes forming a dense undergrowth in sal or miscellaneous forest; and *Micromelium pubescens*, Bl., a small evergreen tree sometimes, as in the Duars, forming a characteristic under-story in sal forest of a moist type, producing masses of strongly-smelling white flowers towards the end of the cold season. A widely distributed small thorny tree, characteristic of dry open forests, and very common in the dry zone of Upper Burma, is *Limonia acidissima*, Linn., while *Feronia Elephantum*, Correa, is a thorny tree also found in dry open forests and cultivated in many parts of India for the sake of its fruit. By far the most important fruit trees belong to the genus *Citrus*: the cultivated species and varieties include (1) *C. medica*, Linn., (a) Var. *medica* proper, the citron, (b) Var. *Limonum*, the lemon, (c) Var. *acida*, the sour lime, and (d) Var. *Limetta*, the sweet lime; (2) *C. Aurantium*, Linn., the orange; (3) *C. decumana*, Linn., the pumelo or shaddock. *C. Hystrix*, DC., vern. *shauknu*, Burm., is a wild species found in Burma and sometimes cultivated in that province. Wild specimens of *C. medica*, and less commonly of *C. Aurantium*, are occasionally met with in the forest, usually in moist shady places, but the position of these trees, along paths and near villages or camping grounds, on old village sites, &c., leads to the conclusion that in most if not all cases they are either escapes from cultivation or have sprung from seed brought by human agency. The species of *Citrus* are cultivated in India in a variety of climates, and do not appear to be exacting in this respect. For a full account of this genus the reader is referred to Brandis's *Forest Flora of North-west and Central India*, 1874, p. 50, while a useful account of the propagation of the cultivated varieties in India, which is carried out by budding, will be found in a paper by W. Burns and H. P. Paranjpye in the *Poona Agricultural College Magazine*, 1913, reproduced in the *Tropical Agriculturist*, vol. xlii, Feb. 1914, p. 117.

AEGLE, Correa.

Aegle Marmelos, Correa. Bael tree. Vern. *Bél*, Hind.; *Bela*, Beng.; *Vilva*, Tam.; *Maredu*, Tel.; *Bila patri*, Kan.; *Ókshit*, Burm. (Fig. 68.)

A small or moderate-sized deciduous tree, reaching a height of 40 ft., the branches armed with straight spines. Trunk often somewhat fluted; bark grey, somewhat corky on the outside. Leaves trifoliate, aromatic. It is one of the sacred trees of India. The wood, which is hard, is used for agricultural and other implements; the chief value of the tree lies in its fruits, which are used medicinally for dysentery and diarrhoea and for making sherbet. The pulp is used to strengthen mortar.

DISTRIBUTION AND HABITAT. Wild in the sub-Himalayan tract, central and southern India, and Burma. Frequently planted all over India and Burma. In its wild state the tree is found as a rule in dry deciduous forests, associated in the sub-Himalayan tract with *Schleichera trijuga*, *Holarrhena antidysenterica*, *Wrightia tomentosa*, *Cassia Fistula*, *Phyllanthus Emblica*, *Bauhinia racemosa*, *Bridelia retusa*, *Odina Wodier*, *Lagerstroemia parviflora*, *Zizy-*

phus Xylopyrus, *Acacia Catechu*, *Anogeissus latifolia*, *Diospyros tomentosa*, and other species. In the Bahraich district a peculiar type of gregarious bael forest is found in patches of varying extent on flat ground with a stiff clay soil. On these patches the bael either grows almost pure or is mixed with *Acacia Catechu* and *Diospyros tomentosa*; the crop is open, the trees are stunted, and there is usually a light crop of grass on the ground (see Fig. 69). It is probable that the bael has retained possession of these patches of stiff ground to the exclusion of most other species because of its capacity for growing on unfavourable situations, in which it is favoured by its great power of reproduction by root-suckers; in the patches in question the bulk of the young trees can be seen to be root-suckers. Among the drier types of forest in which the tree is found may be mentioned the deciduous forests of South Merwara, where the bael is found associated with *Anogeissus latifolia*, *Schrebera swietenoides*, *Dalbergia latifolia*, *Diospyros Melanoxyton*, *Cassia Fistula*, *Randia dumetorum*, and other species.

In its wild state the tree occurs in regions where the absolute maximum shade temperature varies from 105° to over 115° F., the absolute minimum from 30° to 45° F., and the normal rainfall from about 23 to 80 in.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The tree is leafless or nearly so for a short time in the hot season, about April–May. The greenish white very fragrant flowers appear from May to July; they cover the trees and are visited by innumerable bees. The young fruit quickly commences to form, being at first elongated and not round; it becomes full-sized or nearly so by December, and in some cases even shows signs of beginning to ripen then. In northern India it does not actually ripen till April to June of the year after flowering, and some fruits may remain on the tree till the end of July before falling. The fruits are globose, greyish green turning yellow on ripening, 2–4 in. in diameter in the wild state and larger when cultivated, with a hard smooth woody aromatic rind filled with sweet orange-yellow thick mucilaginous pulp in which numerous seeds are embedded. The seeds (Fig. 71, *a*) are oblong, compressed, about 0.3 in. long, with a woolly mucous testa: about 150 weigh 1 oz. Tests carried out at Dehra Dun have shown that the seed does not retain its vitality long, and on the ground is very subject to the attacks of ants, which destroy much of it.

When the hard-rinded fruit falls to the ground, unless broken open by animals it is soon attacked by white ants, while the seeds go bad or are destroyed by insects. The fruits, however, are frequently found broken open by animals, deer breaking them with their hoofs, while pigs and monkeys, and possibly bears and jackals, also eat the pulp: in this way the seed is able to reach the ground before it perishes. Bael seedlings may be seen in the forks of trees and other places to which the seed is taken by the agency of birds.

GERMINATION (Fig. 71, *b–e*). Hypogeous. The whitish radicle emerges from the end of the seed and descends: the short cotyledonary petioles simultaneously elongate, enabling the plumule to emerge and ascend. The fleshy cotyledons remain within the testa below ground.

THE SEEDLING (Fig. 71).

Roots: primary root long, moderately thick, terete, tapering, white at first, becoming yellow: lateral roots few or moderate in number, fibrous,

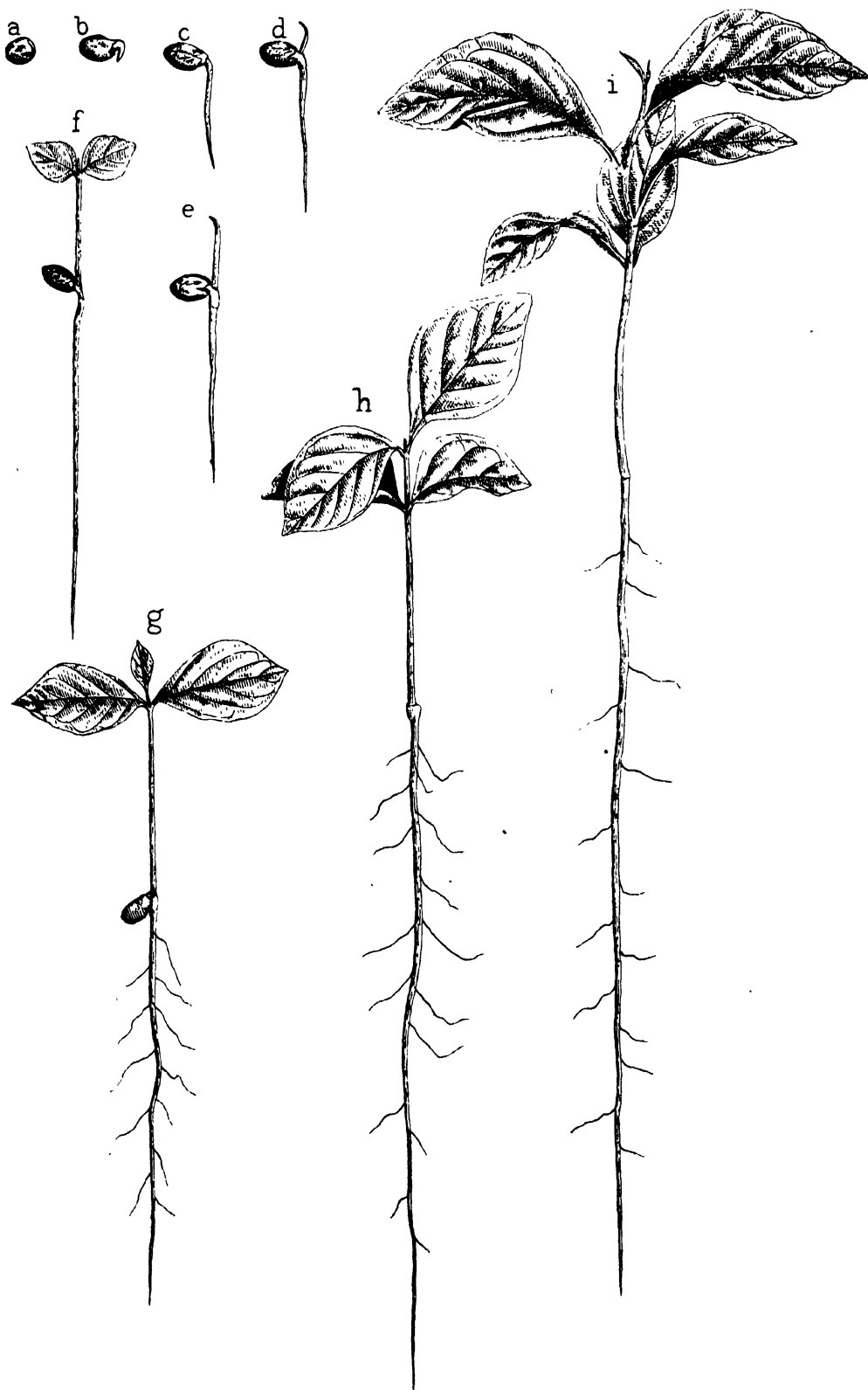


FIG. 71. *Aegle Marmelos*. Seedling $\times \frac{1}{2}$.
 a, seed ; b-e, germination stages ; f-i, development of seedling during first season.

distributed down main root. *Hypocotyl* distinct from the root, 0.1–0.15 in. long, thick, white, subterranean. *Cotyledons* subterranean : petiole 0.1 in. long, curved to side of stem : lamina 0.3–0.35 in. by 0.25–0.3 in., thick, fleshy, white, orbicular or broadly elliptical, outer surface rounded, smooth, inner flattened in contact. *Stem* erect, terete or slightly compressed, woody, green, pubescent ; first internode (between cotyledons and first pair of foliage leaves) 1.7–2.2 in., subsequent internodes 0.1–0.6 in. long. *Leaves* simple in first two seasons, trifoliate leaves appearing later, first pair opposite, second pair opposite or sub-opposite, subsequent leaves alternate, exstipulate, sub-sessile or with short petioles up to 0.1 in. long, channelled above. Lamina 1–2.7 in. by 0.6–1.5 in., ovate or rhomboidal, apex acute, base acute or slightly decurrent, crenate or crenate serrate, dark green, glabrous or glabrescent, with aromatic glandular dots, venation arcuate, lateral veins 5–8 pairs.

The development of the seedling is very slow. At the end of the first season the stem is ordinarily 2–3 in. high with three to five leaves, and the taproot is 8–10 in. long. By the end of the second season the stem does not ordinarily reach a height of more than 4–6 in. The young plants are apt to die back in frosty localities, but have good power of recovery.

SILVICULTURAL CHARACTERS. The tree is ordinarily found in dry localities unfavourable to the majority of species, and in this respect it may be considered a drought-hardy species. In the abnormal drought of 1907 and 1908 in the forests of Oudh it proved to be decidedly hardy ; in the drought of 1899 and 1900 in central India it suffered severely under very unfavourable conditions of soil and climate. Ordinarily it is fairly frost-hardy, but it suffered to some extent in the abnormal frost of 1905 in northern India. Although the tree grows in open forest it is capable of standing a fair amount of shade. It coppices moderately well, and produces root-suckers in abundance. The root-system is superficial, the lateral roots spreading to some distance from the tree.

NATURAL REPRODUCTION. Natural reproduction by seed is not as a rule good, the seed being somewhat perishable and much liable to insect attacks ; as mentioned above, its dissemination depends on the agency of animals and birds. Regeneration by root-suckers is at times very plentiful, and this appears to be the chief mode of reproduction.

ARTIFICIAL REPRODUCTION. Seed should be obtained from fruits collected off the trees and not off the ground. The seeds should be washed to remove the pulp, dried for a few days, and, if necessary, coated with red lead to keep off ants. They should be sown fresh about April or May, covered with earth and watered. The seedlings bear transplanting well, but in view of their slow development should not be transplanted until the rains of the second season or even the third season in the case of backward plants.

RATE OF GROWTH. The rate of growth is slow. Measurements by Mr. C. M. McCrie in Gorakhpur, United Provinces, of coppice-shoots nine and eleven years old showed an average height of 8 ft. and 9 ft. 6 in., and an average girth of 2.2 in. and 2.4 in. respectively, while sal coppice in the same coupes showed an average height of 15 ft. 7 in. and 19 ft. 2 in. respectively.

ORDER XIV. SIMARUBACEAE

This is a small and comparatively unimportant order so far as Indian forestry is concerned.

AILANTHUS, Desf.

Species 1. *A. excelsa*, Roxb.; 2. *A. malabarica*, DC.; 3. *A. glandulosa*, Desf.

1. *Ailanthus excelsa*, Roxb. Vern. *Maharukh*, Hind.; *Arua*, Rajputana; *Maha nim*, Uriya; *Pedda manu*, Tel.

A large deciduous tree. Bark light grey and smooth in young trees, with large conspicuous leaf-scars, rough, granular, and greyish brown in older ones. Leaves pinnately compound, up to 3 ft. long with 8–14 pairs of leaflets. In seedlings and saplings imparipinnate leaves are the rule for the first three or four years, after which the terminal leaflet becomes reduced in size, or is represented by a mere prolongation of the rachis, and finally the typical abruptly paripinnate leaves are formed about the fourth or fifth season. The wood, which is soft and white, is used for packing-cases, and is reported to make good match splints.

DISTRIBUTION AND HABITAT. Indigenous in the Indian Peninsula, and often planted in different parts of India. It is found in mixed deciduous forest and, in the Central Provinces, also in sal forest; it is common round villages.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The panicles of small yellowish flowers appear in February–March, and the fruits ripen in May–June. The fruit (Fig. 72, a) is a red one-seeded samara, 2–3 in. long by 0.5–0.6 in. wide, prominently veined, acute at both ends and twisted at the base; about 260 to 300 weigh 1 oz. The fruit being winged is adapted for dissemination by wind. A considerable proportion of the seed loses its vitality if kept for one year.

GERMINATION (Fig. 72, b–e). Epigeous. The radicle and plumule emerge from the cell and break through the winged covering, the cotyledons being carried up and the testa usually left inside the fruit. The hypocotyl arches somewhat at first, soon straightening: there is a decided kink at its base owing to the effort of the seedling to escape from the cell in which the seed is enclosed.

THE SEEDLING (Fig. 72).

Roots: primary root moderately long, terete, tapering: lateral roots moderate in number and length, fibrous. *Hypocotyl* distinct from the root, with a well-marked bend at the junction, 1–1.5 in. long, terete, tapering upwards, white turning green, minutely tomentose. *Cotyledons*: petiole 0.1 in. long or less, flattened above, tomentose: lamina 0.6–0.7 in. by 0.4–0.5 in., foliaceous, somewhat fleshy, elliptical ovate, apex rounded, base rounded or sub-truncate, entire, green, glabrous, venation pinnate reticulate. *Stem* erect, terete, green, minutely tomentose. *Leaves*, first few sub-opposite, subsequent leaves alternate, earlier leaves trifoliate, subsequent leaves imparipinnate with number of leaflets gradually increasing, paripinnate leaves forming about the fourth or fifth season. Stipules absent. Common petiole of trifoliate leaves 0.3–0.5 in. long, tomentose. Leaflets opposite or sub-opposite, shortly petiolate



FIG. 72. *Ailanthus excelsa*. Seedling $\times \frac{1}{2}$.
 a fruit ; b-e, germination stages ; f-h, early development of seedling.

or sub-sessile, pubescent or glabrescent ; terminal leaflet 0.7–1.2 in. by 0.3–0.6 in., ovate, acute or acuminate, coarsely serrate or nearly lobed ; lateral leaflets 0.4–0.8 in. by 0.2–0.4 in., obliquely ovate lanceolate, acute or acuminate, coarsely serrate.

The cotyledons usually persist for about 2–3 months, when they turn yellow and fall. By the end of the first season the seedlings reach a height of 2–9 in., according to whether they have been watered and weeded or not : the more vigorous plants then have 7 or 8 trifoliate leaves, followed by a few 5-foliate ones. From the second season, if the plants are well weeded, growth is rapid ; in experimental sowings at Dehra Dun the following dimensions were reached :

End of second season—height 2 ft. or more.

End of third season—height 8 ft. or more.

End of fourth season—height 14 ft., girth 12½ in.

Where weeding is not carried out they seldom reach a height of 1 ft. by the end of the second season. In northern India the seedlings drop their leaves about February, and new shoots appear at the end of February or in March. Seedlings are much subject to insect attacks in their early stages ; they are sensitive to frost, and are also apt to die off in dry weather or where the drainage is bad. Heavy weed-growth prevents their development and causes high mortality.

SILVICULTURAL CHARACTERS. The silvicultural characters of this tree have not yet been fully studied. It coppices well and produces root-suckers. It is said to be easily broken by wind.

NATURAL REPRODUCTION. As a rule natural reproduction in the forest is not good. This is probably due to the sensitiveness of the seedling, to its intolerance of heavy weed-growth, and to the fact that the seed requires bare ground for successful germination. Experiments at Dehra Dun have shown that under natural conditions germination takes place early in the first rainy season after the fall of the seed.

ARTIFICIAL REPRODUCTION. Plants can be raised easily from seed or from cuttings. Large cuttings strike readily, and root-cuttings may also be used to produce shoots. For artificial propagation by seed a light porous soil is necessary. The seed should be sown in May or June in well-raised seed-beds in drills about 9 in. apart, water being given regularly but sparingly, as the seedlings will not stand an excess of it. Under favourable conditions germination takes place 1–2 weeks after sowing. Regular weeding should be carried out, and in the cold season the plants should be protected if frost is to be feared. The seedlings will be ready to transplant during the rains of the second season ; they stand the operation well. At Dehra Dun direct sowings, both irrigated and unirrigated, have succeeded well, but it was found that thorough weeding was essential to success.

RATE OF GROWTH. The rate of growth is known to be rapid, but no statistics are available.

2. *Ailanthus malabarica*, DC. Vern. *Dhup*, Kan. ; *Peru*, Tam.

A large ornamental deciduous tree with a tall cylindrical trunk and grey bark with a thin corky layer on the outside, yellow mottled and fibrous inside. The tree occurs in evergreen forests of the Western Ghats, from the Konkan

southwards and on the eastern slopes of the Pegu Yoma in Burma ; it is often planted for ornament in southern India. It flowers in February–March, and the fruit, a reddish brown samara, 2.5–3 in. long, ripens in April–May. The wood, which is soft and white, is not used ; but the tree yields a fragrant resin used as incense and in native medicine.

3. *Ailanthus glandulosa*, Desf.

A large tree indigenous in China and sometimes planted in India. It has been tried in the North-West Frontier Province with some success ; experience there has shown that it can be transplanted easily and requires little water, while it grows fast, produces fertile seed in abundance at an early age, and spreads rapidly by root-suckers.

ORDER XV. BURSERACEAE

An order containing a few trees with useful timber and others important in Indian forestry owing to their abundance or wide distribution. Most of the trees are resinous. Among trees of moist regions may be mentioned the various species of *Canarium*, all large resinous trees. *Bursera serrata*, Colebr. (vern. *Najor*, Ass. ; *Kandior*, Kol ; *Armū*, Santal ; *Thadi*, Burm.) is a moderate-sized to large tree, evergreen or nearly so, found commonly along streams, in ravines, or on rocky ground in cool situations, in Assam, Chittagong, Chota Nagpur, Orissa, northern Circars, and Burma ; rare in the Central Provinces. It stands moderate shade in youth.

Genera 1. *BOSWELLIA*, Roxb. ; 2. *GARUGA*, Roxb.

1. *BOSWELLIA*, Roxb.

Boswellia serrata, Roxb. Syn. *B. thurifera*, Colebr. ; *B. glabra*, Roxb. Vern. *Salai*, *saler*, Hind. ; *Anduga*, Tel. (Fig. 70.)

A moderate-sized to large deciduous, usually gregarious, tree with light spreading crown, somewhat drooping branches and compound imparipinnate leaves 12–18 in. long ; bark greenish grey to yellow or reddish, fairly thick, smooth, exfoliating in thin papery flakes, resinous inside. The tree ordinarily reaches a height of 30–50 ft., and a girth of 4–6 ft. Wood moderately hard, whitish, resinous, with a small brown heartwood, used for rough planking, boxes, well-construction, &c., and for match manufacture. A fragrant gum-resin exudes from wounds in the bark, and is used as incense and in medicine : it shows promise of furnishing, on distillation, rosin and turpentine of some economic value. The branches are lopped for buffalo fodder in Ajmer. The tree is a most useful one for clothing dry, hot, barren hills.

DISTRIBUTION AND HABITAT. The tree is common and usually gregarious on dry hills throughout the greater part of India ; it does not occur in Assam or Burma. In northern India it is found on the southern slopes of the Siwalik hills flanking the Himalaya, on dry sandstone ridges associated with *Zizyphus Xylopyrus*, *Odina Wodier*, *Anogeissus latifolia*, *Acacia Catechu*, *Buchanania latifolia*, *Nyctanthes Arbor-tristis*, and other species. It is common on the dry hills of Chota Nagpur. In Rajputana it occupies the drier ridges of hills on metamorphic rocks, chiefly gneiss and schists, either pure or mixed with *Odina Wodier*, *Sterculia urens*, and a few other species. In the drier parts of

Bombay, the Central Provinces, Berar, and the Peninsula generally it occupies the hotter slopes and ridges of hills, usually on trap and sometimes on gneiss and schist, with *Sterculia urens*, *Anogeissus latifolia*, *Odina Wodier*, *Acacia Catechu*, and a few other species, and sometimes *Hardwickia binata* or stunted teak. On the poorest and shallowest soil, or where the ground is ferruginous, it is found pure or nearly so ; here it is able to thrive and to reach fair dimensions where every other species, with the possible exception of *Sterculia urens*, remains stunted. It always forms comparatively open forests.

In its natural habitat the absolute maximum shade temperature varies from 110° to 120° F., the absolute minimum from 30° to 45° F., and the normal rainfall from 20 to 50 in.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The leaves turn yellowish to light brown in December, and commence to fall in quantity, the curled up leaflets covering the ground and crackling under foot. At this season the trees are recognizable at a distance by the light brown colour of their foliage. By the end of January to the beginning of March the trees are leafless, and remain so till the new leaves appear in May or June. The racemes of rather small white or pale pink fragrant flowers appear at the ends of the branches from the end of January to March or April, when the tree is leafless or nearly so, and the fruits ripen in May-June. The fruit is a 3-gonous drupe with a woody pericarp, splitting into three valves and containing three hard pyrenes, each surrounded by a membranous wing.

SILVICULTURAL CHARACTERS. The *salai* is a strong light-demander. It has great vitality ; in order to kill trees by girdling, in the interests of more valuable species, the cut has to be made both deep and broad. It stands fire better than almost any other species in the dry tracts which it frequents. In the abnormal drought of 1899-1900 in the Indian Peninsula it suffered only slightly ; it is, however, somewhat frost-tender. It is not readily browsed by cattle. Porcupines do much damage to *salai* trees in certain localities by eating off the bark and sometimes girdling and killing the trees. Pigs have a great partiality for the seedlings, which they grub up. Cases of damage by gales have been recorded, the trees being uprooted and thrown down. The *salai* produces root-suckers, but its power of producing coppice- and pollard-shoots is variable. In Bhandara, Central Provinces, Mr. Haines notes that it never fails to coppice if cut in the dry weather and freed from overhanging cover. In Jubbulpur several instances are recorded of *salai* under 3 ft. in girth coppiced ten years previously having produced vigorous shoots which remained in a healthy condition up to date. In Ajmer it usually coppices well, while in the drier parts of Berar coppicing is reported to have given very fair results. On the other hand it is reported that the tree cannot be relied on for coppice reproduction in Nimar. A series of experiments in Narsinghpur, in which pollarding was carried out as well as coppicing both flush with the ground and at a height of 1 to 2 ft., resulted in almost complete failure. Experiments in Saugor showed that *salai* in that district neither coppices nor pollards well : it was found that in the first year or two pollard-shoots grew better than coppice, but many died off in the second and third years, and eventually the percentage of success was practically the same in either case, though the coppice-shoots tended to become more vigorous than the pollard-shoots. The

precise reason of this variation in coppicing power has not yet been ascertained. It has been suggested that it may be due to geological formation : thus in Ajmer and Bhandara, where the tree coppices well, the rock is mainly gneiss, schist, and quartzite, while on most of the trap areas it coppices poorly.

NATURAL REPRODUCTION. Natural reproduction is usually good, even on the poorest ground ; some of this is due to root-suckers, but the tree also reproduces well from seed.

ARTIFICIAL REPRODUCTION. The *salai* reproduces well from large cuttings ; these should be planted in the rainy season when the soil is damp. Attempts to raise it artificially in Berar by line sowings with the aid of field crops resulted in failure, owing to the fact that the seedlings were practically all rooted up by pigs. As regards the capacity of the tree for growing from cuttings, Mr. C. M. McCrie informed me of a case which occurred in the Saugor district, Central Provinces, in a year of severe drought, when many kinds of trees were dying for want of moisture : some posts of *salai* were stuck in a row in the ground to form a barrier to prevent the passage of cattle, and in spite of the intense drought many of the posts sprouted and developed flourishing shoots.

RATE OF GROWTH. Statistics of the rate of growth of trees are not available. Where coppice-shoots are produced they grow rapidly. In Bhandara, shoots reached a height of 6 ft. 11 in. in one year, and 20 ft. in three years. In Nimar, measurements of one-year-old coppice-shoots on very poor shallow trap soil in seven different plots showed a maximum and minimum height of 7 ft. 2 in. and 2 ft. respectively, and an average height varying from 4 ft. to 6 ft. 1 in.

2. GARUGA, Roxb.

Garuga pinnata, Roxb. Vern. *Kharpat*, *kaikar*, Hind. ; *Kudak*, Mar. ; *Garuga*, *gargu*, Tel. ; *Chinyôk*, Burm. (Fig. 73.)

A large deciduous tree with compound imparipinnate leaves, which are often covered with red galls. Bark thick, soft, greyish brown, exfoliating in large irregular hard flakes, red inside. Sapwood large and white ; heartwood reddish brown, moderately hard. Wood not very durable, used for inferior building and other purposes. Although its economic value is not great, the tree is of interest as an accessory species owing to its wide distribution in important types of forest.

DISTRIBUTION AND HABITAT. The tree is widely distributed throughout India and Burma, chiefly in mixed deciduous forests ; it is a common associate of teak and sal. It is a typically sporadic species, and does not occur gregariously, except in patches of limited extent. In the miscellaneous hilly forests of drier regions it is most prevalent on cool aspects and in ravines, but elsewhere it is not particular as to aspect. In Burma it is common in the lower mixed forests of the plains as well as in the upper mixed forests.

In its natural habitat the absolute maximum shade temperature ordinarily varies from 105° to 115° F., the absolute minimum from 30° to 55° F., and the normal rainfall from 40 to 100 in. or more.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The tree is ordinarily leafless for several months during the dry season, but the time of leaf-fall varies



FIG. 73. *Garuga pinnata*, Dehra Dun, United Provinces.



FIG. 74. *Cedrela Toona*, Dehra Dun, United Provinces.

greatly. Before falling the leaves turn red, the leaflets falling separately and the rachis following: in northern India they commence to fall during November, but many trees remain in full leaf, particularly in cool, moist localities, till December or even January. The tree ordinarily remains leafless until April or May, but in moist localities the new leaves may appear as early as March. The flower-buds appear at the ends of the bare branches in February or March, and in March or April the leafless trees are conspicuous with feathery masses of greenish white flowers. The fruits develop very quickly, the round green drupes commencing to form before all the flowers have fallen. In northern India the fruits become full sized by June, but are not ripe until July and August, and do not all fall until September. The fruit is a globose drupe, yellowish green when ripe, containing 2-4 extremely hard stones about 0.3 in. in diameter.

GERMINATION. Epigeous. The hard stone splits in two, the radicle pushes its way downwards and the 5-partite cotyledons emerge shortly afterwards; the fragments of the stone remain in or on the ground.

THE SEEDLING. During the first season the seedling develops fairly rapidly after germination, reaching under natural conditions a height of 4-6 in. or more by the end of the season. During the second and subsequent years growth is rapid even under natural conditions where no watering or weeding is done, the plants reaching a height of 1½ to 3 ft. by the end of the second season, and a maximum height of over 10 ft. and a girth of 5 in. by the end of the third season. The seedlings do not appear to mind a moderate growth of grass and weeds, but if suppressed by shade they show poor development. They are frost-tender, but have great power of recovery. Growth ceases about October and new growth starts in March-April. The leaves of seedlings fall from December to March.

SILVICULTURAL CHARACTERS. *Garuga pinnata* is a strong light-demander, becoming readily suppressed under shade. It is frost-tender both in the seedling stage and later, but has good power of recovery; it suffered severely in the abnormal frost of 1905 in northern India. It is also sensitive to drought, and was badly affected in the severe drought of 1899 and 1900 in the Indian Peninsula. It is one of the most fire-resisting species in the localities where it grows, its thick moist bark and recuperative power standing it in good stead. It coppices well and produces root-suckers.

NATURAL REPRODUCTION. The seeds are to some extent distributed by birds, which eat the acid flesh of the fruits and scatter the stones to a distance from the tree. Many fruits, however, fall to the ground round the trees. They quickly turn black, emitting a strong odour resembling freshly cut teak-wood and blackening the ground around them. The fleshy portion of the fruit decays or shrivels up and is washed away by rain or eaten by white ants, leaving the stones exposed. When the fruits fall the rainy season is at its height, and under natural conditions the seed does not ordinarily germinate that year. The stones lie on the ground, many becoming half buried with the action of the rain, and thus they remain through the succeeding cold and hot seasons. At the commencement of the next rainy season germination commences, and seedlings may often be found in abundance in the neighbourhood of seed-bearers; they are easily recognized from the peculiar deeply cleft

cotyledons with five narrow lobes. Some of the seed lies dormant over two dry seasons, and does not germinate until the beginning of the second rainy season after the fall of the fruit. Two essential factors for successful reproduction are abundance of light and freedom from overhead suppression. The seedlings appear to have no difficulty in making their way through a moderate growth of grass and low weed growth, such as they are almost bound to encounter, since the seed has no opportunity of germinating on new ground, but lies ungerminated for one and sometimes two years.

ARTIFICIAL REPRODUCTION. The ripe fruits should be collected about July, placed in drills in seed-beds, very lightly covered with earth, and regularly watered during the dry season. Most of the seed will germinate early in the rains of the following year, though some may germinate sooner : the seedlings can be transplanted without difficulty about six weeks to two months after germination, when they are about 4 or 5 in. high. Transplanting, however, checks the growth, and better development is obtained by direct sowing. As in the case of *Boswellia serrata*, large cuttings of *Garuga pinnata* strike readily. A few years ago young trees of various species planted in the Lachiwala camping ground near Dehra Dun were surrounded by posts of *Garuga* about 6 ft. high and 1 ft. in girth, to which barbed wire was nailed to keep off cattle ; some of the posts sprouted and developed into flourishing trees, which eventually suppressed the trees they were intended to protect.

RATE OF GROWTH. The rate of growth is fast, particularly in the case of trees up to middle age. Coppice-shoots of *Garuga* as a rule grow more rapidly than those of any species associated with it. In the Siwaliks, coppice-shoots were measured which had reached a height of 35 ft. in ten years, while coppice measurements in Gorakhpur, United Provinces, showed an average height of 50 ft. and a girth of 1 ft. 10 in. in sixteen years, sal having reached an average height of 18 ft. 3 in. and a girth of 6 in. in the same coupe. In more or less dense crops the girth development is comparatively slow, owing to the light-demanding character of the tree.

ORDER XVI. MELIACEAE

This is an important order in Indian forestry, containing as it does several trees with useful and valuable timbers ; the wood is most commonly reddish and mahogany-like.

Genera 1. *AZADIRACHTA*, Adr. Juss. ; 2. *MELIA*, Linn. ; 3. *CARAPA*, Aublet ; 4. *SOYMIDA*, Adr. Juss. ; 5. *CHICKRASSIA*, Adr. Juss. ; 6. *CECRELA*, Linn. ; 7. *CHLOROXYLON*, DC. ; 8. *DYSOXYLUM*, Blume ; 9. *SANDORICUM*, Cav. ; 10. *AMOORA*, Roxb. ; 11. *SWIETENIA*, Linn.

1. *AZADIRACHTA*, Adr. Juss.

Azadirachta indica, A. Juss. Syn. *Melia indica*, Brandis ; *M. Azadirachta*, Linn. Neem, margosa. Vern. *Nim*, Hind. ; *Yepa*, Tel. ; *Tamaka*, Burm.

A moderate-sized to large, usually evergreen tree, with a fairly dense rounded crown and glabrous imparipinnate leaves ; bark moderately thick, furrowed longitudinally and obliquely, dark grey, reddish brown inside. The



FIG. 75. *Azadirachta indica*—SEEDLING $\times \frac{3}{4}$

a—Fruit

b - f—Germination stages

g, h -Development of seedling during first season

heartwood is red, hard, and durable, and is used for house-building, furniture, and many other purposes; the bark, gum, leaves, and flowers are all used in medicine, while the seeds yield an oil used in medicine and for burning.

DISTRIBUTION AND HABITAT. The natural habitat of the tree in India is somewhat difficult to determine. It is common in the open scrub forests of the dry zone of Burma, and is found apparently wild on the Siwalik hills; Gamble says that if wild anywhere in India it is probably so in the forests of the Carnatic and parts of the Deccan. In the Saharanpur Siwaliks I have found it in some quantity on the inner ridges in places where it is difficult to believe it could have spread from cultivated trees. It is cultivated all over India and Burma, more especially in the drier parts of the country, and has evidently become wild in many localities as an escape from cultivation. It is a very useful roadside or avenue tree in dry and moderately dry climates, thriving as a rule where the normal rainfall varies from 18 to 45 in., and where the maximum shade temperature may be as much as 120° F., though it will not stand excessive cold. It will grow on most kinds of soil, does well on black cotton soil, and does not do badly even on clay. It thrives better than most other species on dry stony shallow soil with a waterless subsoil, or in places where there is a hard calcareous or clay pan not far from the surface. It will not grow well on land liable to inundation.

LEAF-SHEDDING, FLOWERING, AND FRUITING. Only in dry localities does the tree become almost leafless for a brief period; otherwise it is always evergreen, the new leaves appearing in March–April before the old ones have all fallen. The panicles of small white flowers, smelling of honey, appear from March to May, and the fruit ripens from June to August. The fruit (Fig. 75, *a*) is a smooth ellipsoidal drupe 0.5–0.7 in. long, greenish yellow when ripe, one-celled and one-seeded or sometimes two-seeded. The seed does not retain its vitality long.

GERMINATION (Fig. 75, *b-f*). Epigeous. The true testa of the seed is a brown papery covering inside the cartilaginous putamen of the drupe. The radicle emerges from the end of the seed and the hypocotyl arches, withdrawing the cotyledons from the two coverings, and in straightening raising them above ground; the two coverings are either left in the ground or carried up over the cotyledons, from which they eventually drop to the ground.

THE SEEDLING (Fig. 75).

Roots: primary root moderately long, terete, tapering; lateral roots moderate in number and length, fibrous, distributed down main root. **Hypocotyl** distinct from root, 0.8–1.7 in. long, terete, cylindrical or tapering slightly upwards, white soon turning green, glabrous. **Cotyledons** sub-sessile or with petioles up to 0.05 in. long; lamina 0.4–0.5 in. by 2.5–3 in., thick, fleshy, elliptical, apex rounded, base sagittate, outer surface convex, inner flattened in contact, entire, green, glabrous. **Stem** erect, terete or slightly compressed, glabrous; internodes 0.2–1.3 in. long, the first (above the cotyledons) usually longer than those succeeding. **Leaves**, first pair usually opposite, subsequent leaves opposite to alternate, first few trifoliate, later leaves 5-foliate. Stipules absent. **Rachis** 0.3–1 in. long, glabrous, channelled above. **Lateral leaflets** opposite, terminal leaflet somewhat larger than lateral ones; leaflets sessile or sub-sessile, 0.8–1.3 in. by 0.3–0.6 in., ovate lanceolate, acuminate, unequally serrate, often more or less 3-lobed.

During the first season the seedling shows moderate development,

ordinarily reaching a height of 4–8 in. by the end of the year. Experiments carried out at Dehra Dun have shown that development is much retarded by weed-growth, and that regular weeding greatly stimulates the growth and vigour of the seedling. In these experiments it was found that if weeded and moderately irrigated, seedlings reached a height of 2 to 4½ ft. by the end of the second season, and a height of 5 to 7 ft. by the end of the third season : if weeded and not irrigated they reached a height of 1 ft. 8 in. to 3 ft. 3 in. by the end of the second season. Where weeding was not carried out the seedlings showed very poor development, and were eventually killed by suppression and frost. In northern India the growth of the seedlings ceases about October–November, and the new shoots appear about March. The seedlings are very frost-tender, and when killed down to ground-level have little power of recovery ; they are intolerant of an excess of moisture in the soil, the taproot tending to rot.

SILVICULTURAL CHARACTERS. The neem is a light-demander, but has great capacity for pushing its way through thorny scrub in youth ; in this respect it resembles *Bombax malabaricum*. It is very frost-tender, especially in the seedling and sapling stages. Its capacity for thriving on poor dry ground and its intolerance of an excess of moisture in the soil have already been alluded to. It coppices well and produces root-suckers, especially in dry localities. It is not readily browsed by cattle and goats ; it is, however, recognized as fodder suitable for camels. In some localities porcupines damage and sometimes girdle and kill the trees by gnawing off the bark round the base.

NATURAL REPRODUCTION. Under natural conditions the seed ordinarily reaches the ground in the rainy season, and germination takes place in one to two weeks. Although the tree is believed not to be indigenous in India except to a very limited extent it often reproduces naturally with tolerable freedom : in this it is aided by its capacity for establishing itself under the protection of thorny bushes and its hardiness on dry poor soil, provided it is not subjected to frost.

ARTIFICIAL REPRODUCTION. Although the neem can be easily raised in the nursery and transplanted, for forest purposes direct sowings have proved more successful than transplanting. Care is necessary in the collection of the seed : it should be collected off the trees about July when thoroughly ripe, and should be sown as soon after collection as possible. It is advantageous to cover the seed lightly with earth, since seed germinating on the surface of the ground is liable to have the radicle eaten off by insects.

For raising transplants the seed sown in the nursery should be lightly covered with earth and sparingly watered, the soil being kept loose to prevent caking. The seedlings will be fit to transplant during the first rains, when they are 3 to 4 in. high, the taproot then being about 6 in. long : if larger seedlings are required they may be kept another year in the nursery and transplanted early in the rains of the second season, the plants being protected in winter by screens in frosty localities. Transplanting may be carried out successfully after pruning down the stem and roots : this system has been adopted with success in the afforestation of Talankheri hill, Nagpur.

The neem has been employed for afforestation purposes in dry situations

in various localities, as a rule with great success. Different methods of direct sowing have been practised. The following examples may be cited :

1. In the *Indian Forester*, vol. i, p. 201, an account is given of the raising of neem by sowings along with *arhar* on the highest and driest site available in Lucknow. Seed was sown in July 1872 on ground which had been twice ploughed up. No watering was done, but the seedlings were kept free of weeds. In May 1875 the plants were 7 to 8 ft. high, the growth being equal to or better than that of transplants which had been carefully watered and tended.

2. Similar sowings of neem and *arhar* were made in Bahraich forest division, Oudh, in June 1872, no watering being done. Most of the *arhar* died in the first winter, chiefly from frost, though it saved the neem seedlings. Next year the *arhar* recovered somewhat, but died out in the latter part of the second year. The neem suffered much from frost in the second and third winters, but in spite of this the sowings proved very successful, the plants being from 1 to 12 ft. in height when three years old. It was noticed that the plants succeeded best where they were sheltered from the north by existing trees.

3. In the *Indian Forester*, vol. xxxiii, p. 177, Mr. L. S. Osmaston describes experimental sowings of neem on poor ground on trap formation in the Nasik district, Bombay, where the rainfall is about 24 in. Owing to the collection of seed which was largely unripe the success was not as great as it might have been, but such as it was it was greatest in the case of sowings on large mounds $2\frac{1}{4}$ ft. high, 2 ft. in diameter at the top, and 7 ft. in diameter at the base ; here the plants reached a height of 3 ft. after sixteen months from the date of sowing. It was found that one man could prepare five to seven such mounds in a day.

4. In the *Indian Forester*, vol. xxxiii, p. 265, the same writer describes experiments in the raising of neem and other trees by sowings in combination with the cultivation of field crops (sesamum, cotton, and the lesser hemp) in a dry region of the Bombay Deccan with a rainfall of slightly under 20 in. ; this form of raising plantations he considers from experience to be the only successful one in the dry region in question. Operations were conducted where possible by the aid of lessees, a two years' lease being given out and the sowing both of the field crops and of the tree seeds being done, after ploughing and harrowing, with special sowing implements in use in the Deccan. Under one method the lessee cultivated field crops in the first year, and sowed tree seeds as well as field crops during the second year : the sown lines were 1 ft. apart, three lines of field crops to one line of tree seeds, so that the latter were 4 ft. apart. The lessee weeded the lines of tree seedlings twice during the first rains. Under a second method the tree seeds as well as the field crops were sown in strips 4 ft. broad (in four lines 1 ft. apart), alternating with strips of field crops 8 ft. broad ; the lessee weeded the strips of tree seedlings, sowed up blanks in them during the second rains, and continued cultivating field crops between the strips of tree seedlings during the second season. The success of these sowings must depend largely on the rainfall, and provided this is not too scanty they are decidedly promising, the neem reaching a maximum height and girth of 16 ft. and 1 ft. 5 in. by the end of the fourth season.

In the case of departmental sowings the cost of formation up to that time, including collection of seed, ploughing, sowing, and weeding, but not including supervision, amounted to Rs. 28-11-0 per acre, against which receipts from the produce of field crops amounted to Rs. 32, leaving a profit of Rs. 3-5-0 per acre. Thus the raising of plantations with field crops by the agency of lessees should be possible at comparatively small cost, after allowing a reasonable profit to the cultivator.

5. In the Bellary district of Madras great success has been attained by sowing neem seeds on mounds in black cotton soil. This soil is troublesome owing to its tendency to develop cracks in dry weather, and special measures are necessary to counteract this. In the *Indian Forester*, vol. xxxvii, p. 659, Forest Ranger S. Thumboo Naidu describes two methods of carrying out neem sowings on this soil in Bellary. Under one method seed was sown on mounds of dimensions 12 ft. by 4 ft. by $1\frac{1}{2}$ ft., prepared in rows 9 ft. apart: the cracks which developed subsequently were filled in with earth. A year after sowing the plants had reached a maximum height of $4\frac{1}{2}$ ft. The total cost of formation, including the preparation of the mounds, sowing seed, and filling cracks, was Rs. 7-2-0 per acre. Figures given in the circle reports indicate that these mound sowings can be carried out at a cost of little more than Rs. 4 per acre. A second method tried was to sow in furrows 6 ft. apart in land previously ploughed with iron ploughs and levelled. The sides of the furrows were subsequently kept loosened to prevent cracks, and existing cracks were filled in with loose earth; this method succeeded only partially, but in successful places the plants numbered as much as 1,500 per acre, and had a height of 2 to 5 ft. after one year. The total cost of formation in this case amounted to Rs. 13 per acre. Broadcast sowings on land ploughed with iron ploughs gave very poor results.

6. In Ajmer success has been attained by dibbling neem seed under *Euphorbia* bushes.

7. In Berar the neem is grown along with the babul (*Acacia arabica*) in line sowings with the aid of field crops; in this case the neem is regarded more as a secondary species, as pure babul has been found to be much subject to insect attacks. After various trials the following system has been finally adopted: The year's coupe is sold by public auction to a lessee who is required to clear-fell the area, grub out the stumps and plough the land, after which he is permitted to cultivate the area with any field crops he pleases for two years. In the third year, at the commencement of the monsoon, a mixture of 75 per cent. of babul seed and 25 per cent. of neem seed is sown in lines 12 ft. apart, the lessee sowing lines of cotton in between. The babul and neem plants are thereafter kept regularly weeded and thinned, blanks being filled up in the year following the sowing. Cultivation of cotton between the lines is continued as long as is practicable, and cattle, excluding buffaloes, goats, and sheep, are admitted to graze at the rate of one head per acre when the crops are off the ground, this being found beneficial in keeping down grass.

A series of experiments at Dehra Dun has demonstrated the necessity for keeping neem seedlings free from grass and weeds; these not only retard development and cause many casualties, but also intensify damage by frost. Thorough weeding without watering was found to have results almost, if not

quite, equal to those attained by the more expensive process of irrigation with weeding : the loosening of the soil to prevent caking and promote soil-aeration was also found to be most beneficial. In either case direct sowing was found to give better results than transplanting nursery-raised plants.

RATE OF GROWTH. It is sometimes held that the annual rings of neem are not visible or cannot be relied on. Mr. A. W. Lushington, writing in the *Indian Forester*, vol. xxiii, p. 123, states that he examined the rings on some trees felled in a plantation fourteen years old, and found fourteen clearly marked annual rings, with other spurious rings which did not go round but merged into the annual rings ; they seldom went more than a quarter of the way round. In counting rings on neem stumps, care is necessary to avoid these spurious rings. As mentioned above, the rate of development of young plants after the first season is fairly rapid. As a rule trees put on a mean annual girth increment of 0·9 to 1·2 in., though more rapid growth is attained under favourable conditions. Mr. F. Gleadow¹ records a tree sixteen years old with a girth of 4 ft. 4 in. in the Changa Manga irrigated plantation, Punjab.

A small plantation at Motipur in the Bahraich district, United Provinces, formed in 1872 by sowings with field crops, was measured by Mr. M. W. Clifford early in 1916, when forty-four years of age ; as a result of measurements of 32 trees the average girth and height were found to be 2 ft. 8 in. and 35 ft. respectively. The plantation had not been regularly tended, and all the trees were more or less damaged by man and cattle and were rather badly grown, otherwise the growth would doubtless have been faster.

2. MELIA, Linn.

Species 1. *M. Azedarach*, Linn. ; 2. *M. composita*, Willd.

1. **Melia Azedarach**, Linn. Persian lilac, bead tree. Vern. *Bakain*, *drek*, Hind. ; *Yerri vepa*, Tel. ; *Vembu*, Tam. ; *Pejri*, Mar.

A moderate-sized deciduous tree with a short bole and a spreading crown, bipinnate or tripinnate leaves, and a dark grey bark with shallow longitudinal furrows. The tree sometimes reaches fairly large dimensions : Mr. A. E. Wild records one 8 ft. 8 in. in girth at Sataura in Hazara. The wood is used for furniture, agricultural implements, cigar-boxes, &c. ; the fruit-stones are commonly used as beads.

DISTRIBUTION AND HABITAT. Doubtfully indigenous except possibly in Baluchistan and Kashmir. Commonly cultivated for the sake of its handsome flowers and as a roadside tree in various parts of India and Burma, growing in the Himalaya up to 6,000 ft. and even higher. In the Changa Manga plantation near Lahore it is perhaps the commonest species after sissoo and mulberry.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The tree is usually leafless from about December to March or April. The handsome panicles of lilac flowers appear from March to May. The fruits ripen in the cold season, but remain on the tree in yellow clusters during the flowering season, and some may be still on the trees in July. The fruit (Fig. 76, *a*) is a drupe 0·5–0·6 in. long, nearly globose, yellow when ripe, smooth at first, afterwards wrinkled,

¹ Ind. Forester xxv (1899), p. 245

the flesh rather dry : endocarp bony, very hard, usually five-celled and five-seeded. Tests have shown that the seed retains its vitality unimpaired for at least a year : in this it differs from the neem (*Azadirachta indica*). Indeed in one case, seed kept for one year showed a fertility nearly four times as great as fresh seed from the same sample.

If the fruits are sown in nursery beds and watered, germination usually takes place within two or three weeks. Under natural conditions, however, the fruits fall to the ground shortly before or during the rains, and as a rule lie dormant until the following year, germinating during the rains or sometimes earlier in the season if there is much rain.

GERMINATION (Fig. 76, *b-g*). Epigeous. From each fruit-stone one to four seedlings may emerge, the seedlings thus appearing in small groups. The stone splits longitudinally into two pieces and the radicle emerges from the end of the stone through the opening thus made. The hypocotyl arches considerably, the cotyledons extricating themselves and leaving the testa behind.

THE SEEDLING (Fig. 76).

Roots : primary root moderately long, terete, tapering, wiry : lateral roots numerous, long, fibrous, developing early. **Hypocotyl** distinct from the root, 0.6-1.7 in. long, terete, tapering upwards, often with a bend at the base acquired during germination, white turning green, glabrous or very finely pubescent. **Cotyledons** sub-sessile, 0.3-0.5 in. by 0.1-0.15 in., plano-convex, somewhat fleshy, linear oblong, apex and base acute or slightly rounded, entire, green, glabrous. **Stem** erect, terete, green, minutely stellate pubescent ; internodes 0.2-1 in. long. **Leaves** compound, exstipulate ; first pair opposite, trifoliate, 1.1-1.5 in. long, common petiole 0.3-0.4 in. long, flattened above, minutely pubescent, leaflets variously lobed or divided ; subsequent leaves alternate, once or twice pinnate, 3-, 5-, or 7-foliate or with trifoliate lateral pinnae. **Rachis** 0.8-3 in. long, flattened above, minutely pubescent. **Terminal leaflet** 0.8-1.5 in. long, ovate lanceolate, acuminate, base decurrent, irregularly lobed or divided, irregularly serrate ; lateral leaflets opposite or sub-opposite, sub-sessile or with petioles up to 0.2 in. long, obliquely ovate lanceolate, acuminate, irregularly serrate, tripartite or otherwise lobed or in the form of trifoliate pinnae.

During the first season of growth the development of the seedling is moderate ; by the end of the season it reaches a height of a few inches up to about 8-10 in. ; the cotyledons usually persist until the end of the season. Under favourable conditions the development during the second and subsequent seasons is very rapid, a height of 5 to 8 ft. being attained by the end of the second season if regular weeding and watering are carried out ; the tap-root by that time reaches a length of 2 to 3 ft. with considerable thickness and with long lateral roots. Under natural conditions, where no weeding and watering are done, the seedlings ordinarily reach a height of a few inches by the end of the first season of growth—that is, as a rule, the season after the fall of the seed—a height of a few inches to about 3 ft. by the end of the second season, and a maximum height of about 10 ft. by the end of the third season. These measurements were taken at Dehra Dun. Weeding greatly stimulates the development of the seedlings, and suppression retards it. Young plants appear to demand much light from an early stage : they suffer from frost in the winter, but not to the same extent as the neem. In northern India



FIG. 76. *Melia Azedarach*—SEEDLING $\times \frac{3}{4}$

a—Fruit b - g —Germination stages (f shows four seedlings emerging from one fruit)
 h, i —Development of seedling during first season

the growth of the seedlings ceases in November–December, and new growth starts about February–March. The leaves turn yellow and fall about December–January and the new leaves appear in March.

SILVICULTURAL CHARACTERS. The tree is a light-demander. It is more frost-hardy than the neem, though the seedlings suffer to some extent both from frost and from drought. Young plants are subject to browsing by deer. The tree coppices well and throws up root-suckers, especially where the roots are exposed or injured. The roots are chiefly superficial, and the tree is liable to be blown down in consequence; it is also very brittle, and branches are often snapped off, or the main stem is broken in two, by wind. Trees so broken down or cut high produce large numbers of shoots from dormant buds on the stem. Burrs are often produced on the stem, especially near the base. The tree is short-lived.

NATURAL REPRODUCTION. In the Changa Manga plantation the tree regenerates freely from seed.

ARTIFICIAL REPRODUCTION. Artificial propagation may be carried out by direct sowings or by transplanting seedlings from the nursery: the tree can also be grown from cuttings or from transplanted root-suckers. Experiments at Dehra Dun have shown that direct sowing is more successful than transplanting, which appears to check the growth to some extent. The fruits may be most conveniently collected in January–February when the trees are leafless. For raising plants in the nursery the fruits should be sown about 2–3 in. apart in drills from February to April or May and lightly covered with earth; the beds should be regularly watered and weeded, and the seedlings ordinarily commence to appear above ground about three weeks after sowing. Transplanting may be done in the first rains, when the seedlings are a few inches high, or towards the end of the cold weather, before new growth starts; in either case it is advisable to transplant with earth round the roots. Transplanting may also be done during the second rains, when the seedlings are often as much as 5 or 6 ft. high or more. In this case the stem should be cut off at about 4 in. from ground-level and the long taproot pruned down to about 9 in. in length: the plants stand this treatment well, and quickly start shooting up again. In frosty localities, at all events, this method is preferable to transplanting in the first season, since the plants can be protected in the nursery during the first winter. If kept until the second year in the seed-beds the seedlings will require thinning out in order to produce vigorous plants.

If direct sowings are carried out rapid development can be stimulated by thorough and regular weeding. Irrigation also promotes vigorous growth, having a more marked effect on this species than on the neem; irrigated and weeded line sowings, or, failing irrigation, weeded line sowings with or without the aid of field crops, or mound sowings, give most promise of success.

Plantations of this species require thinning from an early stage, as the saplings tend to become weakly if pressed for room.

RATE OF GROWTH. The rate of growth during the sapling stage, as already noted, is very rapid: this rapid growth is kept up for several years, during which a mean annual girth increment of 1.5 to 2 in. is not uncommon, but growth slows down before large dimensions are attained, and trees of large girth are often hollow. The concentric rings, which are annual, are distinct.

2. *Melia composita*, Willd. Syn. *M. robusta*, Roxb. Vern. *Labshi*, Nep. ; *Maha limbu*, Uriya ; *Karibevan*, Kan. ; *Kuriaput*, Mar.

A large handsome deciduous tree of the eastern Himalaya, ascending to 6,000 ft., Assam, Khasi hills, Western Ghats and below *ghat* forests, moist low country of Ceylon, and possibly Burma. The wood is soft and reddish, and is used for planking, ceilings, and other purposes. It is a tree of moist localities and tropical forests, and is occasionally planted for ornament, though the fact that it is leafless for a short time detracts from its value as a roadside tree. The fruit, an ovoid drupe, ripens in the cold season. The growth is rapid. Gamble's specimens gave 2 to 3 rings per inch of radius (mean annual girth increment 2.09–3.14 in.) for a Madras specimen, and 7 rings per inch (mean annual girth increment 0.9 in.) for specimens from Bengal. Talbot says North Kanara specimens showed 3 to 4 rings per inch, giving a mean annual girth increment of 1.57–2.09 in.

3. CARAPA, Aublet.

Evergreen trees, the Indian species littoral.

Species 1. *C. moluccensis*, Lamk. ; 2. *C. obovata*, Bl.

1. *Carapa moluccensis*, Lamk. Syn. *Xylocarpus Granatum*, Willd. Vern. *Pussur*, Sund. ; *Ail*, Chittagong.

A moderate-sized evergreen tree with thin grey bark, attaining a height of 30–50 ft. Wood white, turning red on exposure, hard, used for house-posts, wheel-spokes, tool-handles, planking, and other purposes. This is one of the principal timber trees of the Sundarbans.

DISTRIBUTION AND HABITAT. Coast forests of Bengal, Andamans, Burma, the Malay Peninsula and Islands. In the Sundarbans, an account of which is given under *Heritiera Fomes*, it is now less common than formerly, its timber having been much sought after in the past. It occurs in the north of this tract in areas remote from the sea-face, chiefly in low-lying swampy localities associated with *Amoora cucullata*, *Sonneratia apetala*, *Avicennia officinalis*, and *Barringtonia racemosa*. It is not a gregarious species. In his report on the forests of the North Andamans, 1906, Mr. F. H. Todd says it is found at those points along the coast where the mangrove forest is absent, and grows close down to high tide level, mixed with *Ximenia americana*, *Cynometra ramiflora*, *Mimusops littoralis*, *Hibiscus tiliaceus*, *Heritiera littoralis*, *Mangifera foetida*, and *Calophyllum Inophyllum*, and that it is also found growing on flat alluvial clay close to mangrove swamps along with the last three species. In its natural habitat the tree grows in regions with an absolute maximum shade temperature of 98° to 102° F., an absolute minimum of 45° to 64° F., and a normal rainfall varying from 65 to 200 in. or more.

FRUITING. The fruits, which are globose capsules 3–5 in. in diameter, ripen in the Sundarbans about July. The capsules contain two or three seeds, somewhat variable in size, 2–2.7 in. long by 1.3–2 in. wide by 0.7–1 in. thick, irregularly angular or rounded, brown, with a thick and fibrous testa : in general shape and appearance the seed resembles a large Brazil nut. The seed, which is perishable, germinates soon after falling ; it is buoyant and is thus adapted for dissemination by water.

GERMINATION (Fig. 77, a–c). Hypogeous. A somewhat thick mass of

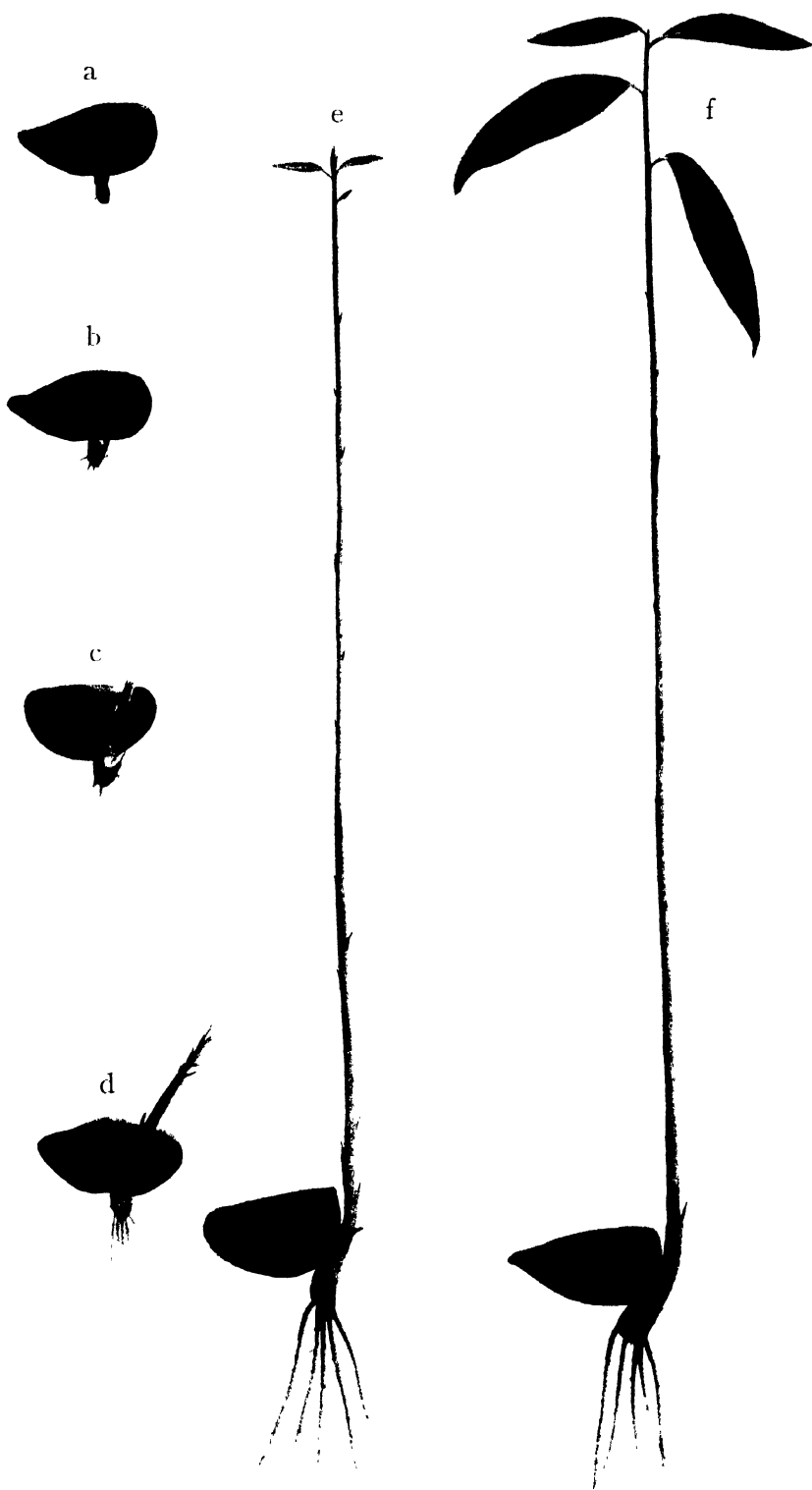


FIG. 77. *Carapa moluccensis* SEEDLING $\times \frac{3}{8}$
 a. Seed; b, c, d, e, f. Development of seedling during first season

soft tissue, corresponding to the hypocotyl, first protrudes from the side of the seed, and from it issue the shoot and the roots, the latter in a cluster.

THE SEEDLING (Fig. 77).

Roots : A number of somewhat thick roots, with numerous fibrous lateral roots, clustered round base of stem. *Hypocotyl* a thick mass from which issue the roots and stem. *Cotyledons* conferruminate in a pinkish fleshy rounded or angular mass conforming to the shape of the seed and remaining within its thick fibrous testa ; petioles 0.2 in. long, broad and flattened. *Stem* erect, moderately thick, terete or slightly compressed, green or reddish, glabrous, in its earlier stages resembling a leafless asparagus shoot. *Leaves* alternate, simple, exstipulate. Petiole 1.5–3 in. long. Lamina 2.5–3.5 in. by 0.6–1 in., oblong lanceolate, acute or acuminate, entire, coriaceous, glabrous. Earlier leaves abortive, scale-like, caducous.

The early development of the seedling is very rapid. Within a month of germination the stem may reach a height of 16 in. or more, and in two months it may be well over 2 ft. in height. The first normal leaves are produced at the top of a considerable length of bare stem, on which the leaves are represented by caducous scales ; the young shoot during the first two or three weeks thus resembles the leafless shoot of an asparagus. This early stem development is an adaptation for bringing the foliage leaves as rapidly as possible out of the reach of floods, the thick starchy cotyledons meanwhile supplying the plant with food. Similar early development occurs in *Heritiera Fomes*, and a further study of the various species of the littoral forests may possibly reveal other instances of the same kind.

SILVICULTURAL CHARACTERS. The silvicultural characters of the tree have not yet been studied in detail. Like several other littoral species it produces pneumatophores.

RATE OF GROWTH. Gamble's specimens showed an average of 6.6 rings per inch of radius, representing a mean annual girth increment of 0.95 in., which is moderately fast. In the Sundarbans a minimum felling limit of 2 ft. girth is fixed for sound trees.

2. *Carapa obovata*, Bl. Syn. *Xylocarpus obovatus*, A. Juss. Vern. *Pinlè òn*, Burm. ; *Dhundol*, Sund. ; *Karambola*, Chittagong.

A smaller tree than the preceding, with a crooked stem and large globose capsules 7–10 in. in diameter. It occurs in littoral forests of the Indian Peninsula, Sundarbans, Chittagong, Burma, the Andamans, Ceylon, extending to the Malay Archipelago, Africa, and Australia. Mr. C. G. Rogers¹ says that in the Andamans it occurs as a rule up the creeks, not immediately adjacent to the sea, along with *Rhizophora mucronata*, *R. conjugata*, *Ceriops Candolleana*, and *Kandelia Rheedii*, but that in certain localities it forms pure forests along the coast where true mangrove forests would have been expected. It does not produce pneumatophores like *C. moluccensis* : the roots are superficial and often ribbon-shaped, with sharp edges.

4. SOYMIDA, Adr. Juss.

Soymida febrifuga, Adr. Juss. Syn. *Swietenia febrifuga*, Roxb. Indian redwood. Vern. *Rohan*, *rohini*, Hind. ; *Sohan*, Uriya ; *Palara*, Mar. ; *Suami*. Kan. ; *Shem*, Tam. ; *Sumi*, Tel.

¹ Report on the Exploration of the Forests of the South Andaman and adjacent Islands, 1906.

A moderate-sized to large almost deciduous tree with a straight trunk, and a fairly thick dark greyish brown bark exfoliating in large plates ; leaves paripinnate, 9–15 in. long, with three to six leaflets 2–4·5 in. long. Wood dark reddish brown, very hard and durable, used for construction, agricultural implements, furniture, and other purposes.

DISTRIBUTION AND HABITAT. Common in the dry forests of the Indian Peninsula, extending northwards to Merwara, the Mirzapur hills, and Chota Nagpur (Hazaribagh, Palamau, &c.). It is particularly common in the dry forests of the Central Provinces, associated with *Chloroxylon Swietenia*, *Terminalia tomentosa*, *Acacia Catechu*, *A. leucophloea*, *Anogeissus latifolia*, *Phyllanthus Emblica*, *Diospyros Melanoxylon*, *Zizyphus Jujuba*, *Z. Xylopyrus*, *Cleistanthus collinus*, *Buchanania latifolia*, *Butea frondosa*, and other species. Where the soil is very poor, consisting largely of calcareous nodules or an excess of quartz, *Soymida* forms a characteristic open type of forest of very poor growth, in which the chief associate species are *Chloroxylon Swietenia* and *Acacia Catechu*, sometimes with *Gardenia* spp., and in which undergrowth is scanty or absent and even grass is limited in quantity. The tree is frequently found on dry stony hills and on laterite. In its natural habitat the absolute maximum shade temperature varies from 105° to 118° F., the absolute minimum from 32° to 50° F., and the normal rainfall from 25 to 60 in.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The young leaves, conspicuous from their red petioles and veins, appear in April–May, before all the old leaves have fallen. The large panicles of small greenish white flowers appear with the new leaves. The capsules ripen and shed their seed in July–August ; they are smooth, 1–2 in. long, black when ripe, five-celled and five-valved, with numerous seeds in each cell. The seeds (Fig. 78, *a*) are soft, flat, winged at both ends, 1·5–1·8 in. by 0·5–0·6 in. (including the wings), with a thin papery testa and a soft felty covering, buff-coloured or light brown, with delicate wings ; about 250 to 350 weigh 1 oz. The seeds are distributed by wind, and their felty covering is not only a protection for the soft seed, but also acts like a sponge in retaining water after rain, a valuable provision during germination in the dry localities which the tree so often frequents. The seed quickly loses its vitality.

GERMINATION (Fig. 78, *b–e*). Epigeous. The radicle emerges first, and the cotyledons then push their way up by the growth of petioles 0·4–0·5 in. long ; the soft covering of the seed, part of which is often washed off by rain during germination, is either raised above ground and dropped with the expansion of the cotyledons or left on or just below ground. The young shoot then develops in the angle between the two petioles of the cotyledons.

THE SEEDLING (Fig. 78).

Roots : primary root long, at first thin, afterwards thickening greatly, terete, tapering, wiry, whitish at first, turning light brown : lateral roots few to moderate in number, fibrous, distributed down main root. *Hypocotyl* not very distinct from root, about 0·2 in. long, scarcely emerging from the soil. **Cotyledons :** petiole 0·4–1 in. long, channelled above, glabrous : lamina 0·6–0·8 in. by 0·6–0·8 in., orbicular or broadly ovate, apex rounded, base widely and prominently sagittate, entire, fleshy, green, glabrous, venation obscure, **Stem** erect, wiry, glabrous ; internodes 0·1–0·2 in. long. **Leaves**, first pair

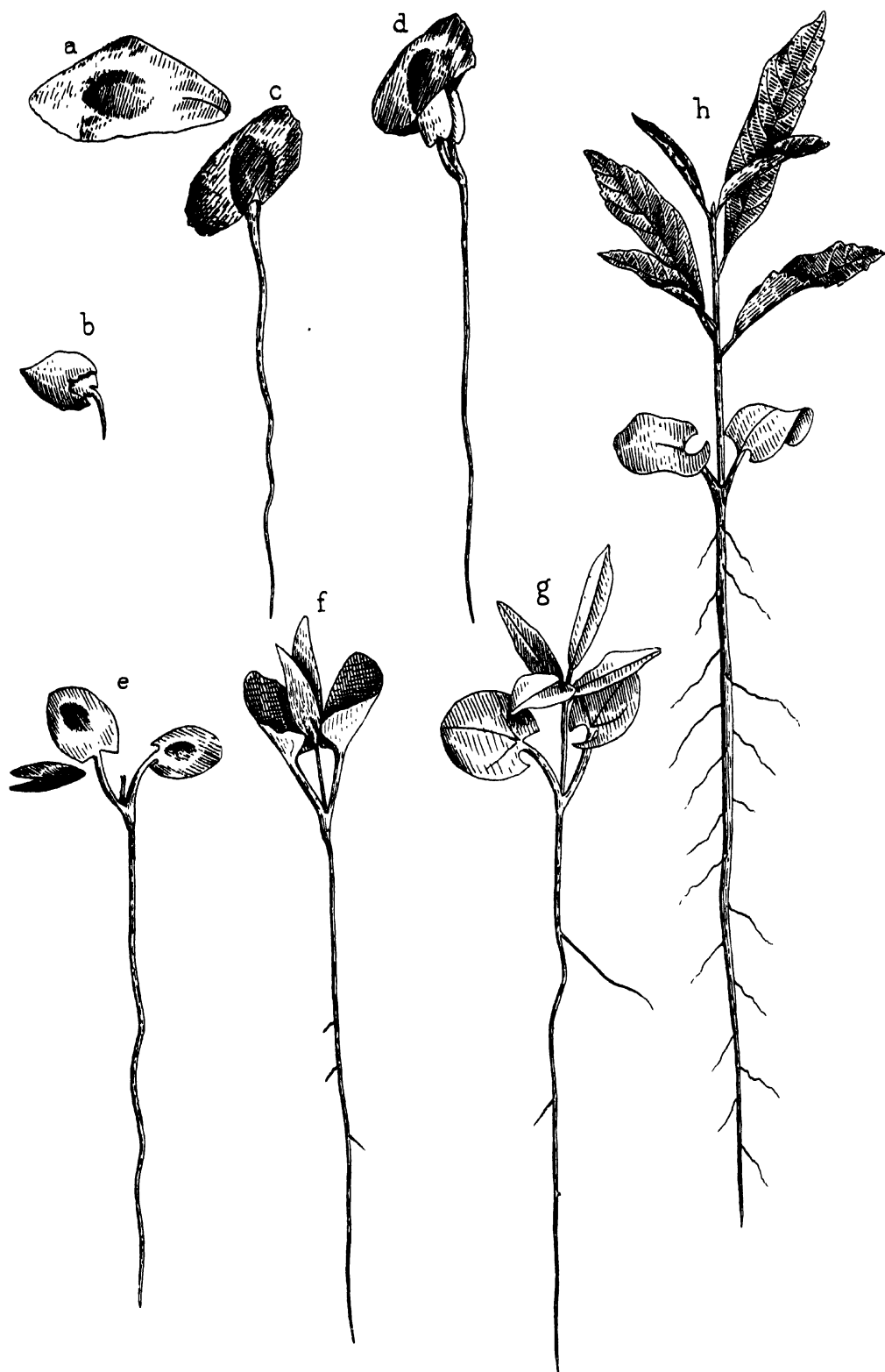


FIG. 78. *Soymida febrifuga*. Seedling $\times \frac{7}{8}$.
 a, seed ; b-e, germination stages ; f-h, development of seedling to end of first season.

opposite or sub-opposite, subsequent leaves alternate, approximate, simple in first season, exstipulate. Petiole 0.1–0.3 in. long, channelled above, often red. Lamina 1.2–4 in. by 0.4–0.6 in., up to 10 in. by 2.5 in. in second year, oblong lanceolate, apex and base acute, serrate, dark green, glabrous, venation prominently reticulate, lateral veins 12–20 pairs, principal veins often red. Compound leaves, first trifoliate then imparipinnate, commence to form in the second or third season.

The development of the seedling is very slow. Observations in Dehra Dun, which, however, is outside the natural habitat of the tree, show that during the first year the stem ordinarily attains a height of only 1–2 in., with a number of simple leaves crowded together; these leaves develop during the first month or two of growth in the rainy season. The cotyledons usually persist for $1\frac{1}{2}$ to 2 months. By the end of the second year the height increases to 2–6 in., or as much as 12 in. if watering is done: by the end of the third and fourth seasons the heights attained are 8–15 in. and 1 ft. 6 in. to over 2 ft. respectively, the height being as much as 4 ft. if watering is done. By the third season a thick stem is developed in the more vigorous plants. Compound leaves begin to appear in the second season, the first ones usually being trifoliate. The earlier compound leaves of seedlings are usually imparipinnate, unlike those of the adult plant. The young leaves are sometimes brilliant red in colour, gradually turning to dark green. On damp badly-drained ground the seedlings are very liable to damp off, and even the seed does so and fails to germinate. The seedlings will not stand the competition of weeds, and respond at once to regular weeding; watering, provided this is moderate and the ground is not stiff, promotes somewhat more rapid growth. The seedlings are very sensitive to frost, which does most damage where weeds are prevalent: they are also subject to defoliation by insects. They show little or no growth after the end of the rains, and growth ceases altogether during the cold season, starting again about March.

SILVICULTURAL CHARACTERS. *Soyimida febrifuga* stands the effects of drought and fire better than most of its associates; in the abnormal drought of 1899–1900 in the Indian Peninsula it escaped injury. It is somewhat frost-tender. It shows xerophytic adaptations in the felty covering of the seed already alluded to, the long thick taproot and the thickened stem of young saplings, the red young leaves of seedlings, and the red veins and petioles of the leaves. Mr. R. S. Pearson¹ classes it as a shade-bearer, and notes that in the Panch Mahals groups of seedlings and poles may be seen growing up happily through vertical shade. At Dehra Dun seedlings were found to require a good deal of light to promote the best development. The tree coppices moderately well and produces root-suckers.

NATURAL REPRODUCTION. Under natural conditions if timely rain falls germination ordinarily commences within a week. The conditions for successful natural reproduction have not yet been sufficiently studied, but as far as observations go factors of importance are a porous well-drained and not too moist soil, bare ground, or at all events the absence of dense weed-growth, freedom from all but the slightest frost, and sufficient light for the development of the seedlings. Some of the natural reproduction met with consists of root-

¹ Ind. Forester, xxxiv (1908), p. 208.

suckers, and in places these may be so plentiful that the tree appears in gregarious masses consisting of sucker shoots.

ARTIFICIAL REPRODUCTION. Experiments carried out in Dehra Dun have shown that direct sowing is more successful than transplanting nursery-raised plants; the latter requires care and is fairly successful in the case of small plants a few weeks old. Direct sowings gave far more success, but it is essential that well-drained ground should be chosen and that the plants should be kept free from weeds. Sowings on ridges about 1 ft. high proved very successful.

RATE OF GROWTH. As far as is known the rate of growth is slow. The slow development of the seedling has already been referred to. Coppice-shoots are of slower growth than the majority of other species of the miscellaneous forests. Measurements of coppice-shoots one year old in Bhandara, Central Provinces, in 1912-13 showed an average height of 3 ft. 10 in. for *Soymida*, 3 ft. 11 in. for *Buchanania latifolia*, 6 ft. 4 in. for *Acacia Catechu*, 6 ft. 6 in. for *Terminalia tomentosa*, and 7 ft. 1 in. for teak.

Six trees planted in 1869 in a mango tope at Trichinopoly were measured by Mr. Rama Rao in 1916, when forty-seven years old, or say fifty years from seed. Their girths at breast-height varied from 5 ft. 2 in. to 7 ft. 5 in. and averaged 6 ft. 1.3 in., while the height of the boles to the first branch varied from 9 ft. 6 in. to 13 ft. and averaged 10 ft. 9 in. The trees stood near a tank, on deep red loam, and the growth in girth may be taken to be much faster than it would be under ordinary forest conditions.¹

5. CHICKRASSIA, Adr. Juss.

The original spelling was *Chukrasia*.

Chickrassia tabularis, A. Juss. (Brandis regards *C. velutina*, Roemer, as a distinct species or very marked variety). Chittagong wood. Vern. *Chikrasi*, Beng.; *Boga poma*, Ass.; *Lal devdari*, pabba, Mar.; *Dalmara*, Kan.; *Sellangatchi*, *gantumali*, Mal.; *Yinma*, Burm.

A very large handsome tree with a tall straight trunk, a spreading crown, and paripinnate leaves. Bark rusty brown, deeply fissured. Talbot says that in North Kanara it has a cylindrical trunk 60-80 ft. to the first branch and 14 ft. in girth. Rama Rao records a tree 18 ft. in girth in a temple grove on the Yelagiris in the Salem district, Madras. Wood reddish brown, hard, very ornamental, and suitable for furniture if well seasoned. The tree is worth cultivation.

DISTRIBUTION AND HABITAT. Sikkim, Assam, Chittagong, Burma, the Andamans, and the Indian Peninsula, chiefly in the Western Ghats; also in Ceylon. The tree is usually found scattered in moist tropical forests on hilly country. Talbot says it is common in the rain-forests of North Kanara and the Konkan. Rama Rao says it is found on all hill ranges in the Salem district, Madras, above 2,500 ft., but that reckless fellings in the past have left but few specimens of large size, which are chiefly confined to temple groves religiously protected by the hill tribes. Bourdillon says it is thinly distributed through the evergreen forests of Travancore at elevations of 1,000 to 2,000 ft. In Burma it is scattered in tropical forests often in moist valleys. In Chittagong it is not uncommon in the hills. Kanjilal says it is fairly common in

¹ Ind. Forester, xliii (1917), p. 19.



FIG. 79. *Chickcrassia tabularis*. Seedling $\times \frac{1}{4}$.
 a, seed ; b-f, germination stages ; g-i, development of seedling to end of first season.

parts of Sibsagar, Assam, where owing to its superficial resemblance to *Cedrela Toona*, although it is considerably taller, it has escaped observation. In its natural habitat the absolute maximum shade temperature varies from 97° to 105° F., the absolute minimum from 37° to 60° F., and the normal rainfall from 70 to 150 in. or more.

LEAF-SHEDDING, FLOWERING, AND FRUITING. Kurz describes the tree as evergreen. Brandis says it is usually deciduous. Bourdillon says it is leafless in the cold weather. The yellowish white flowers appear in April-May and the woody ovoid dark brown capsules, about 1½ in. long, ripen from January to March, the winged seeds escaping and being disseminated by the wind. The empty capsules hang for some time on the tree after opening. The seeds (Fig. 79, a) are brown, flat, with a brown membranous wing twice the length of the remaining portion of the seed, the whole 0.5-0.7 in. by 0.3-0.4 in. Tests at Dehra Dun have shown that the seed will not retain its vitality for a year.

GERMINATION (Fig. 79, b-f). Epigeous. The radicle emerges from the end of the seed opposite the wing; the hypocotyl arches slightly at first and in straightening raises the cotyledons above ground, the testa either remaining on or under the ground or being carried up and dropped when the cotyledons expand.

THE SEEDLING (Fig. 79).

Roots: primary root moderately long, terete, tapering, wiry, pubescent; lateral roots moderately long and numerous, fibrous, distributed down main root. **Hypocotyl** distinct from root, 1-1.4 in. long, terete, tapering slightly upwards, tender at first, becoming wiry, white becoming green, pubescent, arched during germination. **Cotyledons**: petiole up to 0.12 in. long, flattened above, pubescent; lamina 0.4-0.5 in. by 0.25-0.3 in., foliaceous, elliptical, entire, apex and base rounded, glabrous above, minutely pubescent below. **Stem** erect, terete, woody, tomentose; internodes 0.2-0.7 in. long. **Leaves** compound, first pair opposite, subsequent leaves alternate, exstipulate. First pair 1-1.7 in. long, 5-foliate or 3-foliate with terminal leaflet deeply 3-partite. Subsequent leaves 5- or 7-foliate; rachis 1-3 in. long, pubescent; leaflets glabrescent above, puberulous below, very variable; terminal leaflet 1.2-2 in. long, ovate acuminate, deeply 3- or 5-lobed, base decurrent; lateral leaflets alternate or sub-opposite, irregularly ovate, acute or acuminate, variously lobed or divided, with short petioles up to 0.1 in. long.

Experiments at Dehra Dun showed that the growth of the seedling is moderately fast during the first year and very rapid during the second year. By the end of the first season a maximum height of 8 in. was attained, with a taproot about 6-8 in. long. By the end of the second season the plants had reached a height of 3 ft. 9 in. to 6 ft. 10 in., and were very vigorous: by the end of the third season they were 9 to 11 ft. in height, with a girth of 5 to 6 in. at 4 ft. from the ground. The experiments showed that a porous soil, protection from the sun, and only a limited amount of soil moisture are necessary for the germination of the seed and the development of the seedling. A stiff soil or an excess of soil moisture causes the seed to rot and the seedlings to damp off: on the other hand, the seedlings died off from drought if the soil was allowed to dry up. The seedlings suffered less from frost than might have been expected in a tropical species.

SILVICULTURAL CHARACTERS. The silvicultural characters of the tree have not yet been studied in detail. At Dehra Dun young trees were found to

copice well when felled ; they were also found to be subject to the attacks of the toon twig-borer (*Hypsipyla robusta*).

ARTIFICIAL REPRODUCTION. Various trials have been made at Dehra Dun to ascertain the best method of raising the tree artificially. It is necessary to use fresh seed, which should be sown in March or April in light porous soil sheltered from the sun ; watering should be done sparingly, but the soil should never be allowed to dry up as the seedlings are sensitive to drought. Germination ordinarily takes place in ten days to six weeks from date of sowing. The best results were obtained by raising seedlings in well-drained boxes or pots and pricking them out in nursery lines during August when they were a few inches high. Frequent weeding and loosening of the soil is necessary. Seedlings may be planted out either during the first rains or early in the second rains : the latter will probably be found preferable. Fair success has been attained by direct sowings on newly prepared ridges about 1 ft. high.

RATE OF GROWTH. Gamble's specimens gave an average of 8.6 rings per inch of radius, corresponding to a mean annual girth increment of about 0.74 in., which is moderate. Young trees grown at Dehra Dun reached in six years from sowing a height of 18 ft. and a girth of 1 ft. 6 in.

6. CEDRELA, Linn.

Trees with pinnate leaves and red wood resembling open-grained mahogany. Five (possibly more) Indian or Burmese species.

Species 1. *C. Toona*, Roxb. ; 2. *C. serrata*, Royle ; 3. *C. microcarpa*, C. DC.

1. **Cedrela Toona**, Roxb. Toon, red cedar, Moulmein cedar. Vern. *Tun, tuni, maha nim*, Hind. ; *Todu*, Mar. ; *Tundu*, Kan. ; *Thevatharam*, Tam. ; *Poma*, Ass. ; *Thitkado, tawdama*, Burm. (Fig. 74.)

A large deciduous tree with a spreading crown and large paripinnate leaves 1-2 ft. long. Bark 0.4-0.5 in. thick, dark grey, red inside, smooth in young trees, afterwards longitudinally and transversely cracked and exfoliating in irregular woody scales. Wood red, soft, shining, somewhat resembling open-grained mahogany ; much used for furniture, tea-boxes, cigar-boxes, and other purposes, and has been well reported on in the London market. The tree, owing to its rapid growth and the demand for its timber, deserves wider cultivation in localities suitable for it. The fact that its fresh new foliage appears before the commencement of the hot season makes it a very useful avenue tree in northern India. It sometimes attains very large size : Mr. A. K. Glasson measured a log in the Tista valley which contained 500 cub. ft. of timber.

DISTRIBUTION AND HABITAT. Sub-Himalayan tract and valleys of the outer Himalaya up to 4,000 ft., Chittagong, Assam, Burma, Chota Nagpur, Western Ghats and other hills of the Indian Peninsula. Frequently cultivated. In the western sub-Himalayan tract it is found chiefly in shady ravines and along streams, and often (as in the Dehra Dun valley) in swamp forests associated with *Trewia nudiflora*, *Ficus glomerata*, *Pterospermum acerifolium*, *Bischofia javanica*, *Albizia procera*, and other trees typical of moist situations. Farther east it is found in ravines of the outer hills and along the banks of streams, extending into Sikkim, Bhutan, and valleys farther east. Mr. W. R. Jacob says it is found in the lower forest of Bhutan up to 4,000 ft. and some-

times higher, associated with *Duabanga sonneratioides*, *Terminalia myriocarpa*, *Michelia Champaca*, *Castanopsis indica*, and *Schima Wallichii*, and that occasionally patches of very fine toon trees occur. Mr. A. J. W. Milroy found it in the lower forests of the Abor country associated with *Castanopsis tribuloides*, *Dysoxylum Hamiltonii*, *Terminalia myriocarpa*, *Duabanga sonneratioides*, *Amoora Wallichii*, and others. It is met with in various localities throughout the Duars tract of Bengal and Assam, where it springs up readily on abandoned cultivation and on deep alluvial ground near rivers, associated with *Trewia nudiflora*. It occurs in certain valleys in Chota Nagpur. In the Central Provinces it is found in Balaghat and Bilaspur along valleys (Haines). Talbot says it is more or less abundant in the evergreen rain and monsoon forests of the Konkan and North Kanara, and is found in the dry forests of the Akrani, Khandesh. In southern India it occurs mainly in evergreen forests. In Burma it is found in tropical forests. Generally speaking, in its wild state it frequents moist localities, such as ravines, banks of streams, and even swamps, but if tended and watered in youth it is capable of growing in comparatively dry climates and situations, and has been extensively grown as a roadside tree in northern India. In its natural habitat the absolute maximum shade temperature varies from 95° to 110° F., the absolute minimum from 30° to 60° F., and the normal rainfall from 45 to 160 in. or more. Actually, however, it is cultivated in localities where the temperature reaches 120° and sinks below 30° F., and where the rainfall may be as low as 30 in.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The time of shedding of the old leaves and appearance of the new ones varies greatly. In moist shady localities the leaves are retained longer than in drier situations; sometimes, in fact, the tree is said to be evergreen. In northern India the old leaves as a rule fall in December, but in certain cases the tree may remain in full leaf until February. The new leaves usually appear at the end of January and during February. When young they are dark red in colour; they develop rapidly, changing to bright green. The tree is extremely handsome when the new green foliage is out. Kurz says it sheds its leaves in the hot season in Burma. Bourdillon says that in Tranvancore it drops its leaves in September and is bare for some time.

In the Duars the flowers appear in February; in north-western India they do not usually appear till March or April. The small white flowers are arranged in lax panicles, and the petals quickly fall, whitening the ground around the trees. The five-valved capsules (Fig. 80, *a*, *b*), 0.7–1 in. long, in pendulous clusters, ripen in May and June (northern India), and the winged seeds escape at different times from the end of May till July, covering the ground for some distance around the trees; in the early rains they are washed into heaps. The clusters of empty capsules remain long on the tree; they may be seen hanging during the cold season when the trees are leafless, many persisting until February or March when the flowers are out. The seeds are light brown with a membranous wing at either end, 0.5–0.6 in. long including the wings: they are very light and are easily blown about by the wind: about 8,000 to 12,000 weigh 1 oz. Different samples of fresh seed were found to have a fertility varying from 60 to 80 per cent., but seed kept for one year failed to germinate. Records of seed-years maintained for several years in

different parts of the United Provinces, Bengal, and Assam show that the tree usually seeds abundantly every year. The dates of flowering and fruiting given above refer to northern India; those given by various authorities in different localities are: (1) Burma, Fl. March–April, Fr. October–November (Kurz); (2) Bombay, Fl. January, Fr. March–April (Talbot); (3) Travancore, Fl. November to January, Fr. August to October (Bourdillon); (4) southern India, Fl. April–May (Beddome); (5) Central Provinces, Fl. March–April, Fr. May–June (Haines); (6) Chota Nagpur, Fl. March–April, Fr. June–July (Haines).

GERMINATION (Fig. 80, c–g). Epigeous. The radicle emerges from one end of the seed, the hypocotyl arches slightly, soon straightening and carrying the testa, with wings, above the ground; the testa quickly drops with the expansion of the cotyledons.

THE SEEDLING (Fig. 80).

Roots: primary root at first short and thin, afterwards long, much thickened and almost fleshy, terete, tapering, white turning yellowish brown: lateral roots numerous, long, fibrous. **Hypocotyl** distinct from root, 0.8–1.3 in. long, thin, terete, cylindrical, delicate, green, minutely tomentose, slightly arched during germination. **Cotyledons:** petiole 0.1 in. long, flattened above, minutely tomentose: lamina 0.3–0.4 in. by 0.2–0.25 in., foliaceous, elliptical or ovate, entire, apex rounded, base obtuse or acute, green, minutely pubescent at base, elsewhere glabrous. **Stem** erect, terete, delicate at first, afterwards wiry or woody, minutely tomentose; internodes 0.2–0.5 in. long. **Leaves** exstipulate, first pair simple or trifoliate, opposite or sub-opposite, subsequent leaves compound, alternate, earlier leaves trifoliate, later leaves to end of first season imparipinnate, 5- or 7-foliate. Simple leaves with petiole 0.15–0.3 in. long, channelled above, pubescent; lamina 0.3–0.7 in. long, pubescent or glabrescent, palminerved, variable, usually more or less tripartite, sometimes only slightly lobed, sometimes nearly trifoliate, lobes entire or coarsely and irregularly serrate or crenate. Compound leaves (first season) with rachis 0.3–0.8 in. long, leaflets variable, usually more or less 3-lobed, glabrous above, slightly pubescent beneath; terminal leaflet up to 1 by 0.6 in., lateral leaflets up to 0.6 by 0.3 in. Leaves of second season imparipinnate with three or more pairs of lateral leaflets; rachis 1.5–3.5 in. long, tomentose; leaflets 1–2.5 in. long, lanceolate or ovate lanceolate, acuminate, base acute, serrate or entire, glabrous above, pubescent beneath, venation pinnate.

During the first season the development of the seedling is moderate, a height of 4 to 9 in. being attained under favourable conditions. Although the seedlings make their way without difficulty through low and somewhat scanty weed-growth they are sensitive to suppression by dense heavy weeds, and succumb in large numbers where the weed-growth is dense; even if they survive they do not ordinarily attain a height of more than 2 or 3 in. by the end of the season. During the second season the growth is more rapid, a maximum height of over 5 ft. being attained, with a taproot up to 2½ ft. long and 1 in. in diameter. During the second season the toon borer (*Hypsipyla robusta*, Moore) commences its ravages in the rains, boring down the pith of the leading shoots and killing them; this borer, the larva of a pyralid moth, is the cause of much interruption in the development of the young sapling, for although the whole plant is not killed the leading shoot dies down and growth has to be continued from new shoots below the original leader. By the end of the third season a maximum height of 7 ft. and an average height of about 4–6 ft. may be attained under favourable conditions: the growth,



FIG. 80. *Cedrela Toona*- SEEDLING $\times \frac{3}{4}$

a—Fruit capsules before opening b—Fruit capsules opening c - g --Germination stages
h - l - -Development of seedling during first season

however, varies greatly in different individuals even under the same conditions, some remaining comparatively small for no apparent reason.

A plot of natural seedlings at Dehra Dun on ground covered with a low growth of grass and weeds in the open was kept under observation for three years; the heights attained by the end of the first, second, and third seasons respectively were 3–5 in., 18–24 in., and 3–4 ft. These measurements apply to north-western India. Under more favourable climatic conditions the rate of growth is faster: in the Buxa Duars natural saplings 10–14 ft. high have been found on a cultivated area abandoned three years previously.

Toon seedlings are not very sensitive to frost, but require shelter from a hot sun in the first season. Their development is poor on stiff soil, and they respond readily to loosening of the soil during weeding. In northern India they are leafless for a short time in the cold season; the season's growth continues till November or December and new growth begins in February or March.

SILVICULTURAL CHARACTERS. The toon is a moderate light-demander; it stands a moderate amount of shade in youth, the young plants requiring protection from the sun; afterwards it requires full overhead light and crown room for proper development. In its natural state it grows best in small gaps in the forest, where the ground remains moist, and the saplings obtain a certain amount of side protection with complete overhead light. In such places the tree develops a tall clean bole: when grown in the open it tends to branch lower down, forming a large crown. The tree is usually considered to be frost-hardy, both in the seedling stage and later: in the severe frost of 1905 in northern India it generally escaped damage. Parker,¹ however, notes that it does not do well in the Changa Manga plantation near Lahore, where it suffers much from frost when young. It is sensitive to fire, and does not stand much drought. One of the most serious dangers it is exposed to is the toon fruit- and shoot-borer (*Hypsipyla robusta*) referred to above. The life-history of this insect, and measures for dealing with the pest, have been fully described by Mr. C. F. C. Beeson.² Seedlings and saplings are often badly browsed by deer. For its best development the toon requires a deep rich moist loamy soil: it is sometimes grown in comparatively dry situations as a roadside tree, but here it requires watering in youth and is also liable to die off in case of excessive drought. The root-system is largely superficial, and the tree is thus harmful in the neighbourhood of field crops. The branches are often lopped for fodder, resulting in large decayed cavities in the tree.

NATURAL REPRODUCTION. Under natural conditions germination takes place soon after the fall of the seed, early in the rainy season or after the early showers preceding the monsoon. The large quantity of seed produced should ordinarily favour natural reproduction. Much of it, however, which falls before the monsoon breaks and is exposed to alternate wetting and drying with the early showers, is apt to fail: in spite of this a considerable proportion of the crop germinates from seed falling at the right time, and seedlings are often found in quantity round the base of walls and buildings or in other places to which the seed is washed by the rain. Large quantities of germinating seeds and young seedlings, however, are washed away or beaten down during

¹ For. Flora Punjab.

² Ind. For. Records, vol. vii, pt. vii, 1919.

the heavy rains in the early part of the monsoon. In short grass and among weeds the seedlings also appear in quantity, but where weed-growth is heavy they tend to die off before long. Toon saplings are very often found establishing themselves by pushing their way up through bushes and hedges, to the base of which the seed is washed in quantity, protection from the sun being afforded during the establishment of the seedling. In the Duars toon reproduction is sometimes plentiful in rather open forest on deep soft alluvial sandy loam in the neighbourhood of rivers, where it establishes itself even in grazed areas. In the same tract it also regenerates well in the neighbourhood of seed-bearers in fire-protected savannah lands, particularly on abandoned cultivation, where it sometimes appears in quantity, holding its own with other species owing to its fast growth and its capacity for standing a fair amount of shade in youth (see Fig. 81). Experiments in Bengal have shown that by clearing the ground near seed-bearers a good crop of natural reproduction can be induced.

ARTIFICIAL REPRODUCTION. Numerous experiments in the artificial reproduction of the toon have been carried out at Dehra Dun. These show that direct sowings, whether broadcast, in lines with or without the aid of field crops, or on ridges, are not to be relied on owing to the loss occasioned by the washing away of the light seed, even when covered with earth, and the beating down or washing away of the young seedlings by the heavy monsoon rains. Thus, although surviving seedlings develop well if kept regularly weeded, the sowings invariably proved to be patchy and badly stocked. In Bengal, however, some success has been attained by direct sowings on lines cleared through the forest, and also in gaps 30 to 40 ft. square in which the ground was dug up and levelled and the seed was sown broadcast: the seedlings came up plentifully enough to allow of excess plants being transplanted into other parts of the forest. At Dehra Dun the best results have been attained by transplanting nursery-raised seedlings in the second rains, after pruning down the stems and roots.

The seed should be collected off the trees in May (northern India), and not off the ground, as much of the seed which reaches the ground and is exposed to alternate wetting and drying loses its vitality. It should be sown soon after collection in well-raised nursery beds, either broadcast or in drills, and lightly covered with fine earth. Regular watering is necessary, but great care is required to prevent the light seed from being washed away. A good plan is to cover the beds with a thin layer of grass and to water through a fine nozzle, the grass being removed as soon as the seedlings appear; otherwise watering by percolation is successful. In the first season the young seedlings should be protected by screens during the heat of the day unless the beds are shaded by trees. Regular weeding and loosening of the soil is essential. The seedlings require growing room, and if at all congested should be pricked out about 8 in. by 8 in. during the first rains. Transplanting is done early in the second rains, the stem being pruned down to about 3 in. from ground-level and the taproot being pruned down to about 9 in. Seedlings pruned down in this way have been found to transplant successfully and to develop vigorously. Transplanting may also be carried out during the cold season when the plants are leafless.



FIG. 81. *Cedrela Toona*, natural reproduction, 10-14 ft. high, sprung up on cultivation abandoned 3 years previously, Buxa Duars, Bengal.



FIG. 82. *Cedrela serrata* in flower, Kagan Valley, Hazara.

RATE OF GROWTH. The rate of growth is rapid. Gamble's specimens showed a growth varying from 3 to 9 rings per inch of radius, representing a mean annual girth increment of 0.7 to 2.1 in. Brandis's measurements of trees 30 and 35 years old on the Eastern Jumna Canal gave an average growth of $2\frac{1}{2}$ to 3 rings per inch of radius, or a mean annual girth increment of 2.1 to 2.6 in. Gamble records the average measurements of 50 trees in the Kulsi plantation in Assam; these were found to have at an age of 22 years a height of 63 ft. and a girth of 22 in. Ring-countings on 12 stumps in the Tista valley, Bengal, gave a mean annual girth increment of 1.2 in. Two cross-sections in the silvicultural museum at Dehra Dun, from trees grown in that station, showed the following measurements :

1. Age 38 years ; girth 4 ft. 5 in. ; mean annual girth increment (over bark) 1.4 in.
2. Age 33 years ; girth 4 ft. 4 in. ; mean annual girth increment (over bark) 1.6 in.

Mr. F. Gleadow records the mean of four trees 16 years old in the Changa Manga irrigated plantation, Punjab, as 2 ft. $1\frac{1}{2}$ in. in girth and 46 ft. in height. Measurements made in 1907 in plantations in the Thapal Grant estate, Saharanpur district, United Provinces, gave the following results :

1. Age 6 years ; average girth 10.7 in. ; average height 20.6 ft. (mean of 12 trees).
2. Age 16 years ; average girth 2 ft. 7.5 in. ; average height 33.9 ft. (mean of 77 trees).

2. *Cedrela serrata*, Royle. Hill toon. Vern. *Drawi*, *dalli*, *darlu*, *darli*, W. Him.

A moderate-sized to large deciduous tree of the western Himalaya up to 8,000 ft., Manipur, and Upper Burma. Leaves larger than those of *C. Toona*, 2-3 ft. long with 12-24 pairs of leaflets. Bark about 0.5 in. thick, with deep regular longitudinal fissures from an early age. The wood is light red, more open grained than that of the toon, and has an unpleasant odour when fresh : it is used for building, planking, and general carpentry. The tree is leafless during the cold season. The long drooping panicles of pink to nearly white flowers appear from May to July, and the capsules ripen in July-August ; these are about 1 in. long, in pendulous clusters, and remain long on the tree after ripening. The seeds are winged only at the upper end. Fig. 82 shows a tree in flower. The tree produces root-suckers in great abundance ; these sometimes form thickets to a considerable distance round the parent stem. Natural reproduction takes place readily on landslips, among loose boulders, or wherever new ground is exposed, particularly on the sides of ravines where there is a certain amount of moisture. The tree requires well-drained ground and situations which are not too dry. It is often cultivated in the hills for ornament, and Gamble says it has been introduced in Ceylon as a shade tree for tea, and that it is very largely planted for the same purpose over coffee in Java. The growth is rapid, Gamble's specimens showing as much as two rings per inch of radius, representing a mean annual girth increment of 3.14 in.

3. *Cedrela microcarpa*, C. DC. Toon (of the lower Darjeeling hills). Vern. as in *C. Toona* ; *Tawdama*, Upper Burma.

A large evergreen tree with dark brown rough bark. Wood soft, red, used for planking and furniture.

Found throughout the outer ranges of the eastern Himalaya up to 6,000 ft., Assam, and Upper Burma. It grows best in depressions on deep rich soil, and does not thrive well on savannah lands. It should not be grown pure owing to its liability to the attacks of insects, particularly the twig-borer, and to the fact that it tends to produce a short bole unless drawn up by other fast-growing trees. In this respect the low-level birch and alder of the eastern Himalaya are good nurses for it, causing it to produce a long clean bole.

This tree is grown artificially in plantations in the lower Darjeeling hills. The flowers appear in December. The small winged seeds ripen in February and March, and should be collected off the trees and sown with as little delay as possible, as they soon lose their fertility. Plantations are invariably formed by planting out nursery-raised plants. The best results have been obtained in the Mongpoo plantations of the Cinchona department, the treatment being as follows : As soon as the seed is ripe it is sown in nursery beds well manured with leaf-mould, and is lightly covered. The beds are sheltered by means of a double roof of bamboo mats raised about 3 ft. above ground, the roof having a slight slope to allow rain to run off. The beds are kept watered and weeded, and when the seedlings are about three weeks old, they are pricked out about 3 in. apart. By the middle or end of June the seedlings are about 9 in. high, and they are then planted out with balls of earth, the planting holes, 18 in. deep, being dug at least two weeks previously. About a fortnight before the plants are removed from the nursery one of the bamboo mats forming the shelter over them is removed, and about four days later the second mat is removed in order to accustom the seedlings to grow in the open. For the first year after transplanting the young plants are carefully tended. Where the soil tends to become hard it is forked up, and in the case of drought the ground round the roots is covered with grass. In this way excellent results are obtained, plants only three years old sometimes attaining a height of 15 ft. These good results, however, are due in part to the fact that these plantations are formed on land previously under cultivation, where the soil has been well worked and freed from weeds and climbers. In the Forest Department the usual custom has been to sow the seeds in unmanured and unsheltered beds, the seedlings being pricked out about 6 in. apart when 3 in. high and planted out in the forest in their second and even in their third year, when they are usually about 1½ to 2 ft. high. The transplanting of small seedlings is avoided owing to the danger of their being suppressed by weeds and climbers.

7. CHLOROXYLON, DC.

Chloroxylon Swietenia, DC. Syn. *Swietenia Chloroxylon*, Roxb. Satinwood. Vern. *Bhera*, *giryā*, Hind. ; *Billa*, *billu*, Tel. ; *Porasu*, Tam. ; *Mashwal*, Kan. ; *Halda*, *billu*, Mar. ; *Hurgalu*, Mysore. (Fig. 83.)

A moderate-sized deciduous tree with a rather short bole and a spreading



FIG. 83. *Chloroxylon Swietenia*, Belgaum district, Bombay.



84. *Zizyphus Jujuba* pure forest on alluvial sand and shingle, Siwaliks, United Provinces



FIG. 85. *Zizyphus Xylopyrus*, Siwaliks, United Provinces.

light feathery crown with glaucous green, pinnate, aromatic leaves ; bark thick, corky, yellow or light grey, aromatic. In India it does not often attain any great size, but in Ceylon it reaches a girth of 8 or 9 ft., though the bole rarely attains a length of over 30 ft.¹ This tree furnishes the well-known satinwood of commerce, used for all kinds of ornamental work.

DISTRIBUTION AND HABITAT. Common in the dry deciduous forests in the Indian Peninsula, extending as far north as the Satpuras and Chota Nagpur. Mr. Broun says that in Ceylon it is absent only in the south-western portion of the island, which is subject to the south-west monsoon, and from the higher mountain ranges ; and although trees may be seen up to 1,500 ft. elevation. as a rule it may be said that it is not found above 800 ft. or in localities with a rainfall of over 65 in. In the Indian Peninsula it is common in dry types of mixed deciduous forest on metamorphic rocks, sandstone, and laterite, provided the soil is not stiff and clayey ; it will grow on bare rocky ground and on poor soils if they are well drained and contain a large proportion of sand or gravel, and is found even on black cotton soil. It attains comparatively large size on sandy loam in the Chanda district. The satinwood is mixed with a variety of species which differ somewhat according to locality. Its chief associates are *Acacia Catechu*, *Terminalia tomentosa*, *T. Chebula*, *Anogeissus latifolia*, *Buchanania latifolia*, *Phyllanthus Emblica*, *Cleistanthus collinus*, *Cassia Fistula*, *Soymida febrifuga*, *Pterocarpus Marsupium*, *Dalbergia latifolia*, *D. paniculata*, *Albizzia Lebbek*, *A. odoratissima*, *Lagerstroemia parviflora*, *Diospyros Melanoxylon*, *Zizyphus Jujuba*, *Z. Xylopyrus*, *Cochlospermum Gossypium*, and other species typical of dry miscellaneous forest. Within a restricted area (North Arcot and neighbouring localities) *Pterocarpus santalinus* occurs with it, while in some districts *Hardwickia binata* is a common companion. In parts of Madras it occurs on very poor soil, often consisting of red sand, associated with *Albizzia amara*, *Acacia planifrons*, and *Dichrostachys cinerea*. It is sometimes typically found in association with *Soymida febrifuga* on poor calcareous soil with nodules of *kankar*.

In the Indian Peninsula it occurs in dry hot regions where the absolute maximum shade temperature may rise to nearly 120° F., the absolute minimum being 35° F., and the normal rainfall varies from 30 to 60 in.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The tree is usually leafless from February to April or May. The panicles of small cream-coloured flowers appear in March–April, and the fruits ripen from May to August or sometimes later. The capsules are oblong, dark brown, coriaceous, 3-valved, 1–1.5 in. long. The seeds (Fig. 86, *a*) are brown with a broad wing at one end, the whole 0.6–0.8 in. long by 0.15–0.2 in. broad ; the wing is brittle, with one margin broad and angular. The seed does not retain its vitality long. Records of seed-years show that as a general rule the tree seeds abundantly almost every year. The seed is adapted for dissemination by wind to moderate distances.

GERMINATION (Fig. 86, *b–f*). Hypogeous. The radicle emerges at one end of the seed, and if the wing is still present at the time of germination the thin pointed plumule breaks through it. The cotyledons remain underground within the testa.

¹ A. F. Broun in Ind. Forester, xxv (1899), p. 181.

THE SEEDLING (Fig. 86).

Roots : primary root long, thick, terete, tapering, light brown : lateral roots moderate in number and length, thick. *Hypocotyl* somewhat indistinct, short, subterranean. *Cotyledons* sub-sessile or very shortly petiolate, 0.4 in. by 0.15 in., somewhat fleshy, obovate oblong, apex rounded, base broadly sagittate, outer surface slightly convex, inner concave, green, glabrous. *Stem* erect, terete, woody, green at first, turning light brown, young parts minutely pubescent or glabrous ; internodes 0.1–0.3 in. long. *Leaves* compound paripinnate, first pair opposite, sub-opposite or alternate, subsequent leaves alternate ; first few leaves with 3–5 pairs of leaflets, the number increasing in subsequent leaves up to 12 or more leaflets in seedlings one year old. *Rachis* 0.5–2.5 in. long, slender. Leaflets at first opposite or sub-opposite, afterwards alternate, shortly petiolate, 0.2–0.5 in. by 0.15–0.25 in., unequal sided, obliquely ovate or obovate, apex rounded, base obtuse or acute, obscurely crenate or entire, light green to pale glaucous green, paler beneath than above, glabrous, gland-dotted and aromatic.

The germinating seeds and young seedlings are very apt to be washed away by heavy rain, the exposed radicle drying up or being eaten by insects, and the seedling thus perishing. A long stout taproot is, however, quickly formed, and this saves many seedlings which would otherwise be washed away. Seedlings develop well on porous soil free from weeds and badly on stiff soil or where there is a thick growth of weeds, competition with which kills off large numbers of young plants. Experiments carried out at Dehra Dun showed that during the first season the development of the seedlings is very slow, a height of 2–3½ in. being ordinarily attained : at this time the young plants have several small compound leaves. During the second season the growth is faster, a maximum of 18 in. or more being attained by the end of the year under favourable conditions, though where seeds are prevalent the height may not exceed 3–6 in. During the third and fourth seasons the height increases to 2–3 ft. and 5–6 ft. respectively under favourable conditions, but where weeds are prevalent there may be little or no growth.

The leaves of seedlings turn yellow and fall in the cold season, the plants being leafless for a time. Their growth ceases from about October to March, when the new shoots appear. The seedlings are very frost-tender, particularly in the first year or two. In dry hot weather they are also liable to dry up partially or entirely, and benefit much from protection from the sun : they cannot, however, stand anything in the way of suppression, and if they are at all crowded the stronger individuals soon suppress and kill out the weaker ones.

SILVICULTURAL CHARACTERS. The satinwood is a strong light-demander, though the seedlings require protection from the sun in early youth. It is frost-tender, especially in the seedling stage, though severe frosts do not ordinarily occur within its natural habitat. It is easily damaged by fire, but its power of recovery from injury enables it to survive well in areas subjected to burning, hacking, and grazing. In parts of the Indian Peninsula it is much cut for fuel, while as soon as stems become large enough they are cut out for timber. The leaves contain an acrid oil which browsing animals, and even goats, find unpalatable, and this protects the plants from injury ; for this reason the satinwood is often seen thriving on heavily grazed areas where most other species are browsed down. The satinwood is more keenly sought after than any of its associates by deer for the purpose of rubbing the velvet

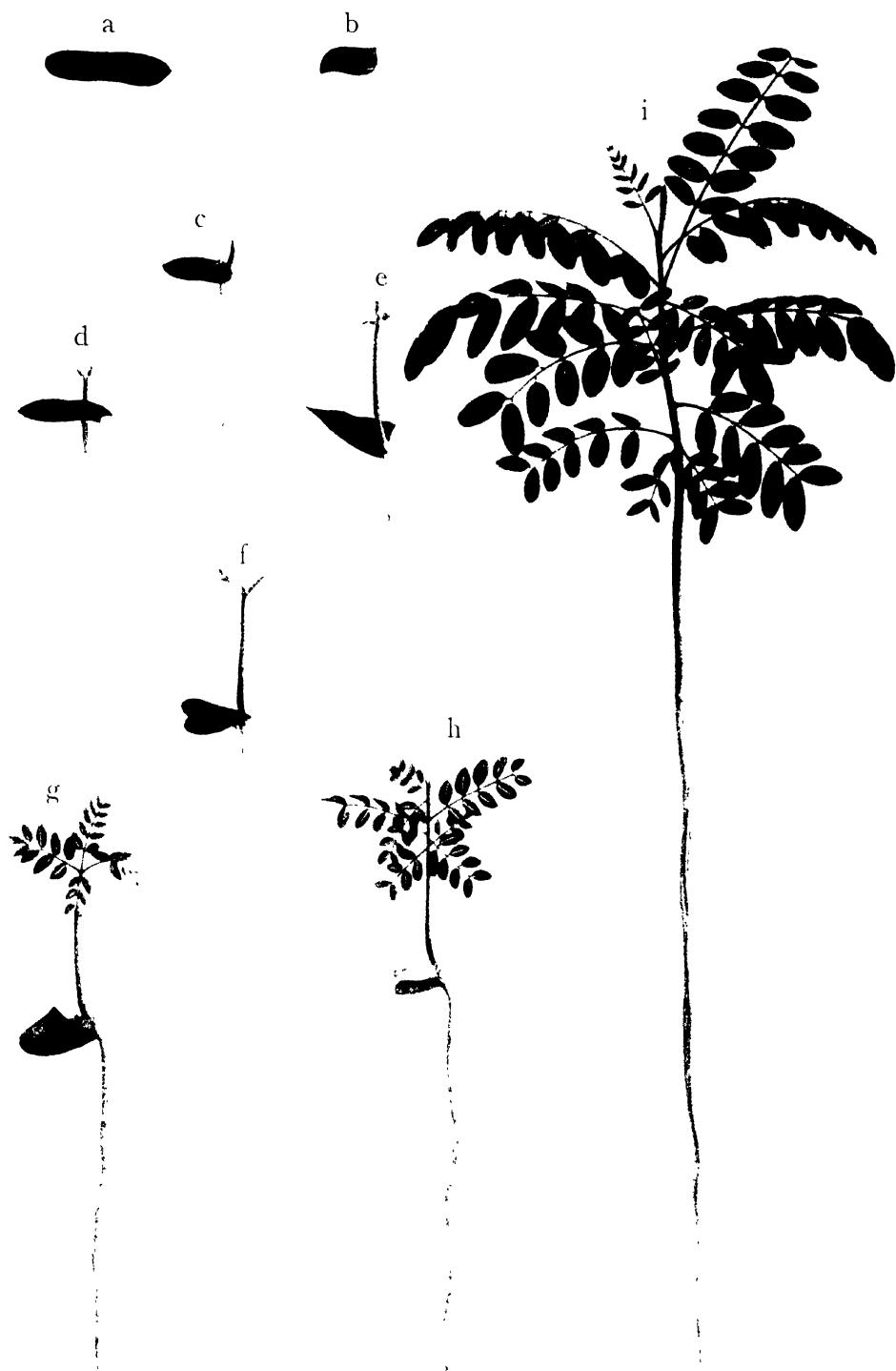


FIG. 86. *Chloroxylon Swietenia*—SEEDLING $\times \frac{7}{8}$

a -Seed b - e--Germination stages f Germinating seed with testa removed to show cotyledons
g - i—Development of seedling during first season

off their antlers, the bark of every tree being rubbed down where deer are plentiful; this is no doubt due mainly to the aromatic nature of the bark. The tree coppices and produces root-suckers, sometimes in great abundance. Recent experiments in North Chanda showed that in hardiness of coppicing—that is, percentage of stools surviving after coppicing—it was equal to *Pterocarpus Marsupium*, 58 per cent. of stools surviving as against 100 per cent. for *Lagerstroemia parviflora*, 98 per cent. for *Phyllanthus Emblica*, 95 per cent. for *Cleistanthus collinus*, 70 per cent. for *Anogeissus latifolia*, and 40 per cent. for *Diospyros Melanoxylon*. As regards insect and fungoid pests, Mr. Broun notes that the tree is liable to the attacks of insects which bore into the pith of the young shoots; also that a large number of trees die from the attacks of the larva of a beetle, probably a longicorn, which tunnels between the bark and the wood. He also mentions that in some parts of Ceylon the trees are liable to the attacks of a fungus which rots the centre of the tree and causes a clean hole sometimes throughout the length of the bole.

NATURAL REPRODUCTION. Under natural conditions, germination takes place during the rainy season, about 1–2 weeks after the fall of the seed, provided there is sufficient rain. The chief factors promoting successful reproduction by seed, where seed-bearers are present, are a well-drained light sandy soil, freedom from heavy weed-growth, protection against the sun in early youth, and thereafter an abundance of light. Numerous seedlings are often found coming up under a moderate cover of bushes such as *Zizyphus Jujuba*, *Carissa spinarum*, *Canthium parviflorum*, and others, while natural reproduction frequently springs up in clearings and along the sides of roads and lines through the forest, often under the shelter of bushes.

ARTIFICIAL REPRODUCTION. The satinwood has never been extensively cultivated artificially. In experiments carried out at Dehra Dun, good success was attained by direct sowings both on well-dug level ground and on raised ridges about 1 ft. high, provided that regular weeding was carried out from the time the seedlings appeared; unweeded sowings proved an entire failure, as did sowings on patches of stiff soil. Seedlings raised on well-prepared soil can be transplanted without much difficulty both in the first rains and in the second rains, provided earth is kept round the roots. As the seedlings are tender to frost and drought it is advisable to keep them under protection in the nursery for the first cold and hot seasons, and transplant them in the second rains. In the forest the necessary protection from the sun in early youth could be secured by sowing in cleared strips sheltered from the south by existing forest growth, or by raising the satinwood between lines of other species introduced a few years beforehand.

SILVICULTURAL TREATMENT. In India the miscellaneous forests containing satinwood are usually worked as coppice-with-standards, the satinwood being one of the trees retained as standards. It would probably not be difficult to obtain natural reproduction by opening the canopy slightly near seed-bearers by girdling or felling inferior species, care being taken not to open so heavily as to promote a strong growth of weeds. When the seedlings appear they would require to be kept free from weeds, while more light would have to be admitted by the further opening and, if necessary, the final removal of the canopy.

RATE OF GROWTH. The rate of growth is somewhat slow. Mr. Broun

estimates the average rate in Ceylon to be 18 in. girth at 20 years, 3 ft. girth at 45 years, $4\frac{1}{2}$ ft. girth at 75 years, and 6 ft. girth at 125 years, representing a mean annual girth increment varying from 0.9 in. in the earlier years to under 0.6 in. in later life. He reckons that the exploitable size may be taken to be 6 ft. girth, but in India it is doubtful if a girth of over 4 ft. would generally be obtained without the trees becoming overmature. In South Vellore, Madras, coppice growth is reported often to exceed $1\frac{1}{2}$ in. in girth per annum.¹

8. DYSOXYLUM, Blume.

A genus comprising several species of evergreen trees, for the most part shade-bearing and growing in moist or evergreen forests. The fruits are leathery capsules of fairly large size, containing large seeds with thick fleshy cotyledons, the seeds losing their vitality comparatively quickly and requiring moist shady ground on which to germinate.

Species, 1. *D. binectariferum*, Hook. f.; 2. *D. malabaricum*, Bedd.

1. *Dysoxylum binectariferum*, Hook. f. Syn. *D. macrocarpum*, Thw.

A moderate-sized to large evergreen tree of Sikkim, Assam, Chittagong, and the Western Ghats.

2. *Dysoxylum malabaricum*, Bedd. Syn. *D. glandulosum*, Talb. White cedar.

A very large evergreen tree of the evergreen forests of the Western Ghats from North Kanara southwards, Coorg, Anamalais, and Travancore. Flowering February to April; fruiting June–July. The wood is yellowish or light red, close grained, hard and elastic. The seed is large and heavy. Bourdillon says that in Travancore its reproduction is not altogether satisfactory, and this is corroborated by Mr. Tireman in Coorg; also that it has a tendency to be gregarious, and is frequently found in company with *Artocarpus hirsuta*, with an undergrowth of cardamoms. He says the growth is fairly fast in young trees, but is much slower later, and mentions a tree planted at Malayattur which attained a height of $27\frac{1}{2}$ ft. and a girth of 12 in. in seven years; its girth was 15 in. in ten years. The wood is used in Cochin for oil-casks.

9. SANDORICUM, Cav.

Sandoricum indicum, Cav. Vern. *Thitto*, Burm.

A moderate-sized ornamental evergreen tree of the tropical forests of Burma, much cultivated for its fruit in Burma, and introduced into southern India and Ceylon. The crown is dense and shady and the leaves are trifoliate with sharp-pointed leaflets. The fruit, which is yellow and velvety when ripe, is about the size of a small orange, and contains a mass of acid edible pulp. The seeds are brown and shiny with a felty arillus covering them. The fruit ripens towards the end of the hot season or in the rains. The cotyledons are oily, and the seeds soon lose their vitality. Seedlings can be most easily raised in baskets, in which they are planted out in the rains the year after sowing. The tree requires a moist climate and rich soil. The wood is red, moderately hard, and is used for building, carts, and boats.

¹ Madras Forest Report, 1915–16.

10. AMOORA, Roxb.

Species 1. *A. Rohituka*, W. and A.; 2. *A. cucullata*, Roxb.

1. *Amoora Rohituka*, W. and A. Vern. *Sohaga*, Oudh; *Bandriphal*, Nep.; *Pitraj*, Beng.; *Thitni*, Burm.

A moderate-sized handsome evergreen shade-bearing tree with a comparatively short bole and a dense spreading crown with large imparipinnate leaves. A widely distributed but seldom very abundant tree of the sub-Himalayan tract from Gonda and Gorakhpur eastwards through the *tarai*, the Bengal and Assam Duars and the outer hills up to 6,000 ft., Assam, Chittagong, Burma, Andamans, Chota Nagpur, western and southern India. Sometimes planted for ornament. The tree is typical of moist shady localities, occurring commonly in ravines, along the shady banks of streams, and in moist tropical forests. The fruit, a yellow leathery 3-valved capsule, 1.5-2 in. in diameter, ripens about January to May. The seeds, which are covered with a scarlet arillus, are oily and somewhat perishable. The seedlings and saplings come up under shade in moist situations, and natural reproduction is often plentiful under and around the parent trees.

2. *Amoora cucullata*, Roxb. Vern. *Amur*, *latmi*, Sund.; *Thitni*, Burm.

A moderate-sized evergreen tree of the coast forests of Bengal and Burma. In the Sundarbans forests (for a description of which see under *Heritiera Fomes*) the tree is now less common than it was formerly, having been much sought after in the past: it is found, together with *Carapa moluccensis*, mainly in low-lying swampy localities towards the north, at a distance from the sea. It is one of the species which send up pneumatophores. The wood, which is red and hard, is used for posts and other purposes.

11. SWIETENIA, Linn.

Two species of *Swietenia* have been more or less extensively cultivated in India in gardens, along roads, and in the forest; these are 1. *S. Mahagoni*, Linn., the true mahogany tree of Central America and Jamaica; and 2. *S. macrophylla*, King, the large-leaved mahogany, which has much larger leaves and capsules.

1. *Swietenia Mahagoni*, Linn. Mahogany.

PAST EXPERIMENTS. The cultivation of the true mahogany was first attempted in India in 1795, when plants from the West Indies were introduced into the Royal Botanic Gardens, Calcutta. It was propagated subsequently by layers, until from 1865 arrangements were made for consignments of seed from the West Indies, and the tree has since then been grown with varying success in many parts of India.

In Bengal, mahogany has succeeded admirably in the Royal Botanic Gardens, Calcutta, there being at present over 200 trees in the Gardens, the oldest dating from 1795: many of the larger trees were blown down in a cyclone in 1864, and their timber fetched the current market price for good mahogany. The survivors are well grown with straight clean boles. At Barrackpore there are also some fine trees: those on the Calcutta maidan are not so good. In the Raj Gardens at Durbhanga there are about a thousand

trees, planted 10 ft. apart about 1882-7. A plantation was formed in the Mohurgong forest in the Darjeeling *tarai* with plants obtained from seed imported in 1865, but it proved a failure. It has also failed at Bamunpokri in the lower Darjeeling hills: here the plants grew well at first, but almost invariably died when about 4-6 ft. high. There are a few trees in the Palamau forest division of Bihar and Orissa, which have done moderately well. In the United Provinces there are trees in good condition in the Government Gardens at Cawnpore, Allahabad, Lucknow, and Saharanpur: at Dehra Dun it has not proved a success. In the Punjab seeds were sown in the Changa Manga and Phillour plantations in 1886, but the experiment was a failure. In the Central Provinces mahogany trees have done fairly well in North Chanda, but their development has not been altogether satisfactory. In Assam experiments made in 1878-9 also resulted in failure: a few plants survived until 1884-5, but all have since died. In Burma various experiments have been made since 1878 in the Tharrawaddy and Rangoon forest divisions, but only a few trees now survive, the majority showing poor development: in some cases this may be attributed to the stiffness of the soil in which they were grown. From 1838 to 1842 mahogany seedlings were planted out with success in Akyab on flat sandy alluvium: the diameter-growth was very rapid (see measurements recorded below), but since the trees were grown in more or less isolated positions, height-growth was sacrificed to crown development. In the Andamans experiments were made in 1898-9 to grow mahogany, but the great majority of plants either died out or showed poor development, mainly owing to insect attacks. In 1906 the survivors, then seven years old, were 15 to 20 ft. in height. In Madras it has been tried in many localities, but in the majority of cases the results have not been satisfactory, owing partly to conditions of soil and climate and partly to insect attacks. Experimental sowings have proved more or less unsatisfactory in Godavari, Kistna, Bellary, Salem, Cuddapah, Nellore, North Arcot, and other districts; in the alluvial soils of the Trichinopoly Paduzais more successful results have been obtained. In the Agri-Horticultural Society's Garden at Madras and in other parts of the town there are trees of various ages up to eighty years or more; most of these have succeeded well. In Madura some trees have succeeded well, and the older ones commenced some years ago to regenerate naturally from seed. In South Canara also there are some fairly well grown trees. In South Malabar experiments began in 1872 and have been continued subsequently, but on the whole the results have not been good, owing partly to unsuitable soil conditions and partly to damage by deer and by insects: *S. macrophylla* has here succeeded better than *S. Mahagoni*. In Bombay there are a few trees, the oldest dating from about 1870, doing well in the Bombay Victoria Gardens, and in the Poona Garden there are also several well-grown trees, probably dating from about the same time. In Baroda varying success has been met with; generally it has been found necessary to water during the first five years.

SILVICULTURAL CHARACTERS AND TREATMENT. The planting of mahogany on a commercial scale in India has been suggested on more than one occasion, and the results of the experiments undertaken hitherto are of value in this connexion. The success attending the cultivation of the mahogany tree has been much greater in gardens than in forest plantations: this would indicate

that the degree of tending and of protection from insects and other sources of injury must influence the results to a great extent, while no doubt, like other *Meliaceae*, it requires careful weeding in the earlier stages. The tree thrives best in a moist warm climate on deep rich soil which should not be stiff; Bourdillon, writing of the tree in Travancore, says it requires an exceptionally free and well drained, even sandy soil, otherwise it is apt to suffer from canker of the shoots. It has also succeeded best so far in localities not far removed from the sea and at elevations not much above sea-level. In dry climates and on poor soils it is a complete failure. At Durbhanga trees have occasionally been subjected to prolonged inundation without any apparent bad effects. The tree fruits well in India and produces fertile seed sometimes at as early an age as 20 years, though as a rule it does not seed until it is about 30–40 years old. It does not stand much shade; experiments at Nilambur in planting it under teak proved a failure. In some localities insects greatly damage the trees, preventing their development and even killing the smaller individuals; among others the toon twig-borer (*Hypsipyla robusta*) does much damage to the young shoots. Seedlings and saplings are subject to injury by deer and pigs, while monkeys damage the trees by breaking the branches for the sake of the succulent twigs and the bark. For artificial propagation the plants are usually raised in baskets or deep narrow pots and planted out when about 1 ft. high, the pots being broken in the planting pits. In India the flowers appear in April–May, and the fruits ripen from October to December. Mr. Rama Rao¹ records a case of normal flowers being produced by a seedling barely ten months old in April 1913 at Quilon in Travancore. Another case of precocious flowering is described by Hemsley in Hooker's *Icones Plantarum*, Plate 2786, under the name of *S. Mahagoni* var. *praecociflora*, from material sent from the Royal Botanic Gardens, Trinidad; the seedlings in question were 6–10 in. high, but in this case the flowers were abnormal in certain respects.

RATE OF GROWTH. In India the rate of growth of the mahogany tree is very rapid in localities where it has been grown with success. Gamble instances measurements recorded by Dr. T. Anderson in 1866 showing that three trees at Calcutta, presumably 73 years of age, had girths of 14 ft. 3 in., 12 ft. 3 in., and 13 ft. respectively, representing a mean annual girth increment of nearly 2.2 in. Trees introduced in 1795 into the Royal Botanic Gardens, Calcutta, had attained in 1864 a girth of 12 ft. (mean annual girth increment 2.1 in.), and in 1907 a girth of 14 to 18 ft. (mean annual girth increment 1.5–1.9 in.) with a height of 120 to 130 ft. Ten trees with a mean age of 58 years, measured at Saharanpur in 1872, had a mean annual girth increment of 1.26 in., representing an average girth of slightly over 6 ft. Mr. J. Nisbet² records measurements made by him at Akyab in 1881 of ten trees then about 42 years old: the total height varied from 36 to 60 ft., the length of bole from 5 to 9 ft., and the girth at 5 ft. from ground-level from 5 ft. 5 in. to 10 ft. 1 in. The average girth was 6 ft. 10 in., representing a mean annual girth increment of 1.95 in. These trees grew for the most part in open situations, and height-growth was sacrificed to crown and girth development. Gamble mentions a section cut at Nilambur showing 2.2 rings per inch of radius, representing a mean annual girth increment of 2.9 in. In the Andamans, young trees eight

¹ Ind. Forester, xxxix (1913), p. 327.

² *Ibid.*, vii (1881–2), p. 250.

years old were 15 to 20 ft. high. In the Bombay Victoria Gardens, trees ten years old had a height of 25 ft., and trees thirty to forty years old a height of 50 to 60 ft. Four trees thirty-five years old, measured at Muzaffarpur in 1913, varied in girth from 7 ft. to 7 ft. 8 in. and averaged 7 ft. 4 in., representing a mean annual girth increment of 2.5 in.; these trees were grown in open situations, and had short boles 6 to 12 ft. in length. Nearly all the measurements quoted above are those of trees grown under more than ordinarily favourable conditions so far as girth development is concerned: in forest plantations a considerably lower rate of growth would have to be allowed for.

2. *Swietenia macrophylla*, King. Large-leaved mahogany.

CULTIVATION IN INDIA. This tree grows even more rapidly and thrives better in India than *S. Mahagoni*, from which it is easily distinguished by its much larger leaves and capsules, the latter being 6 in. long. Seeds believed to have been obtained from Honduras, and labelled 'mahogany', were first introduced into India through the India Office, in 1872. The seedlings were soon noticed to be different from those of the true mahogany, and when the trees flowered and fruited in their twelfth and thirteenth years, the material available was examined by Dr. King, who described the tree as a new species. It is a very ornamental tree and thrives well in many parts of India, growing rapidly and seeding freely at an earlier age than the true mahogany. It grows well as far north as Dehra Dun, where it produces seed at a comparatively early age. The wood is somewhat similar to that of the true mahogany, but is paler in colour, and may possibly not prove to be of such good quality. Mr. A. Wimbush says he was not impressed with a plank cut from a tree eighteen years old removed in thinning the Eddacode plantation, South Malabar, in 1911: it was almost white, with a slight pinkish tinge, and was bored into by some very minute borer. Possibly in the case of older trees the wood may prove to be of better quality. The tree is less exacting as regards both soil and climate than the true mahogany. In South Malabar it has been found to grow well on disintegrated laterite soil, but not on bare laterite: in this district it may be said to have passed the experimental stage, and is now grown in plantations, while the older trees are regenerating naturally from seed. It does not stand much shade, and cannot be grown under teak. It is subject to damage by insects; young saplings are readily browsed by deer and goats, and are uprooted by pigs, while the twigs are, as in the case of the true mahogany, broken by monkeys: the trees are also much barked by deer. Basket planting is the usual method of propagating the tree. In South India it flowers from February to May, and the fruits ripen in December-January.

RATE OF GROWTH. Under favourable conditions the rate of growth is rapid. In the Royal Botanic Gardens, Calcutta, trees planted in 1872 reached a maximum height of 20 ft. in 12 years. In the Peradeniya Gardens, Ceylon, a height of 40 ft. has been reached in 11 years. A tree planted in 1873 at Chathamborai, South Malabar, at an age of 35 years had a height of 95 ft. and a girth of 7 ft. 5 in., and at an age of 39 years had a height of 100 ft. and a girth of 8 ft. 5 in., representing a mean annual girth increment of over 2.5 in. In 1911-12 the trees in the Pokote and Eddacode plantations of South Malabar showed a mean annual girth increment of 2 in., at which rate girths of 6 ft. and 7 ft. might be expected in 31 and 42 years respectively.

ORDER XVII. ILCINEAE

This order, comprising the one genus *Ilex* (holly) with between twenty and thirty species, is of small importance from a forest point of view. The trees are for the most part evergreen hill species with shade-bearing tendencies : several have spinous-toothed leaves.

ILEX, Linn.

Species 1. *I. insignis*, Hook. f.; 2. *I. dipyrena*, Wall.; 3. *I. denticulata*, Wall.; 4. *I. Wightiana*, Wall.

1. *Ilex insignis*, Hook. f. Vern. *Lasuni*, Nep.

A small evergreen tree with large prickly leaves and bright red berries which ripen in the winter : the common holly of Darjeeling.

2. *Ilex dipyrena*, Wall. Himalayan holly. Vern. *Kanderu*, Jaunsar ; *Shangala*, Punjab.

A moderate-sized evergreen tree of the western Himalaya from Bhutan westwards at 5,000 ft. upwards. In favourable situations it ordinarily attains a height of 40–50 ft. and a girth of 4½ ft., though trees of much larger girth have been recorded. Bark light yellowish grey, smooth, often moss-covered, becoming dark greenish brown and rougher in old trees. The leaves are stiffly coriaceous, spinous serrate or entire. The clusters of greenish white flowers appear from April to June, and the dense clusters of red berries commence ripening in October and continue to ripen in the winter, the quantity produced varying in different years. The tree is a strong shade-bearer, and prefers cool damp shady places, particularly along moist ravines.

3. *Ilex denticulata*, Wall.

A large tree of the Nilgiris and Anamalais, common in sholas at 6,000–8,000 ft.

4. *Ilex Wightiana*, Wall.

A large tree of the hills of southern India ; common in the Nilgiri sholas, and conspicuous from its white flowers and red berries. In Travancore at 4,000 ft. in evergreen forest on the Peermerd plateau (Bourdillon).

ORDER XVIII. CELASTRACEAE

This order is of comparatively small importance in Indian forestry, comprising for the most part small trees, shrubs, and climbers. There are several Himalayan species of *Euonymus*, small evergreen or deciduous trees or shrubs, with even-grained compact white or yellowish wood used for carving ; some of these (e.g. *E. tingens*, Wall.) are characterized by a capacity for producing root-suckers in great abundance, especially where the roots are exposed, and are thus useful for consolidating and retaining hill slopes and cuttings.

Genera 1. LOPHOPETALUM, Wight ; 2. ELAEODENDRON, Jacq. f.

1. LOPHOPETALUM, Wight.

Lophopetalum Wightianum, Arn. Vern. *Balpale*, Kan. ; *Venkotta*, Mal.

A very large evergreen tree of the west of the Indian Peninsula from the Konkan southwards, up to 3,000 ft. in the Western Ghats, in evergreen forests.

In Travancore it is common in the evergreen forests and on river banks at low elevations, sometimes ascending to 2,000 ft. (Bourdillon). Fl. January to April; Fr. June–July. Gamble says the wood is much esteemed in South Canara, where it is used for house-building. Bourdillon says it grows fast and could easily be propagated.

2. ELAEOGENDRON, Jacq. f.

Elaeodendron glaucum, Pers. Syn. *E. Roxburghii*, W. and A. Vern. *Bakra, dhebri, jamrasi, chauri*, Hind.; *Tamruj*, Mar.; *Mukarki*, Kan.; *Karuvalli*, Tam.

A deciduous (nearly evergreen) tree, small to moderate sized in drier localities, attaining large dimensions in moist or evergreen forests. Branchlets often reddish, leaves opposite or sub-opposite, dark green and shining above, glaucous beneath. Bark fairly thin, dark grey or reddish, smooth or exfoliating in small quadrangular scales, red inside and exuding a copious watery sap when cut. The wood is used for cabinet-work and picture frames.

DISTRIBUTION AND HABITAT. Though not abundant anywhere the tree is fairly widely scattered throughout many parts of India, in the sub-Himalayan tract and outer Himalaya, Oudh, Chota Nagpur, the Central Provinces, and the Indian Peninsula generally. It is most commonly found in mixed deciduous forests, or scattered in sal forest in the sub-Himalayan tract: on the boulder terraces of the outer Himalaya it is sometimes fairly plentiful, as at Kalsi in the Dehra Dun district. It is often found on clay soil. In the Central Provinces it is common on trap and on metamorphic rock (Haines). In the Western Ghats it attains large dimensions in moist evergreen forest.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The tree is leafless or nearly so in March–April, the new leaves appearing in May (northern India). The dates of flowering and fruiting appear to vary considerably. There are possibly two flowering periods, February to June and September to December. The fruit is a rather dry obovoid drupe 0.4–0.7 in. long; the outer portion dries into a brittle shell, which is filled by the oily seed with a reddish brown papery testa. In some localities the fruits begin to ripen in November, in others not till January, while they continue ripening for some time afterwards. Before ripening they are much subject to attacks of parrots, which break them open to get at the kernel inside. At the time of ripening they are eagerly sought after by hornbills, which probably help to spread the seed. Tests carried out at Dehra Dun showed a fertility of 60 per cent. in fresh seed and 20 per cent. in seed kept for one year.

GERMINATION AND DEVELOPMENT OF SEEDLING. Germination, which is epigeous, takes place under natural conditions at the commencement of the rains: the cotyledons persist for about two to three months. The first pair of foliage leaves are opposite, the subsequent leaves of the seedling being alternate. By the end of the first season the seedlings reach a maximum height of about 7 in. with a dark yellow taproot several inches long; they lose their leaves about January–February or sometimes not till the new shoots appear in March. During the second and third seasons the growth is slow, averaging only about 2–4 in. per annum. Weeding, if carried out from

the time the seed is sown, stimulates development, but the sudden removal of weeds over seedlings previously unweeded is liable to result in the death of the seedlings, which are tender to drought. Numbers of germinating seedlings perish through drying up when the seed germinates on the surface of the ground without becoming covered with earth. The seedlings appear able to struggle successfully against weed-growth, though their development is impeded by it. The seedlings are moderately frost-hardy. They are liable to damage by insects, which sometimes kill them.

SILVICULTURAL CHARACTERS. The tree is a moderate shade-bearer. It is fairly frost-hardy. It produces root-suckers, and frequently regenerates by this means. It is sometimes supposed that regeneration is obtained entirely by root-suckers, the seed being sterile, but, as already noted, tests and experiments at Dehra Dun have shown that this is not the case.

ARTIFICIAL REPRODUCTION. If seed be sown in drills in the nursery in March or April, lightly covered with earth and watered, the seedlings appear above ground in about four or five weeks, and may be planted out during the first rains when a few inches high. They stand transplanting only moderately well, some dying back but as a rule recovering.

RATE OF GROWTH. The rate of growth is slow. Periodical measurements of trees $1\frac{1}{2}$ –3 ft. in girth in three sal sample plots in the Lansdowne division, United Provinces, showed mean annual girth increments of 0.35, 0.11, and 0.20 in. as compared with 0.54, 0.26, and 0.25 in. respectively in the case of sal of the same dimensions.

ORDER XIX. RHAMNACEAE

With the exception of certain members of the genus *Zizyphus*, this order is not an important one silviculturally; it consists mainly of shrubs, some of them climbing or straggling, and small trees of little importance.

ZIZYPHUS, Juss.

Trees or shrubs, some climbing or straggling, usually armed with stipular prickles. The fruit is a drupe, as a rule fleshy; the fruits of many species are devoured by birds and animals, and the seeds are spread by their agency.

Species 1. *Z. Jujuba*, Lam.; 2. *Z. Xylopyrus*, Willd.; 3. *Z. vulgaris*, Lam.; 4. *Z. nummularia*, W. and A.; 5. *Z. Oenoplia*, Mill.; 6. *Z. rugosa*, Lam.

1. *Zizyphus Jujuba*, Lam. Vern. *Ber*, Hind.; *Jelachi*, Kan.; *Bor*, Mar.; *Yellandai*, Tam.; *Regu*, Tel.; *Zi*, Burm. The cultivated form is known as *pewandi ber*, *seo ber*, or *kabuli ber*.

A small to moderate-sized deciduous (almost evergreen) tree with a short bole, spreading rounded crown, and drooping branches armed with stipular prickles. Bark dark grey or nearly black, with long vertical fissures, reddish and fibrous inside. The tree is very variable in size and general appearance, and in the size and shape of its fruits; a low shrubby form is common on grass-lands in many localities. The tree sometimes reaches large dimensions. Mr. E. D. M. Hooper¹ records a tree 80 ft. high, 16 ft. 9 in. in girth at 5 ft.

¹ Ind. Forester, vii (1881–2), p. 259.

from ground-level and 23 ft. at the base, which he found growing on a small knoll on laterite soil on the site of an old village near the Weinganga river, Central Provinces.

The tree is a useful one in furnishing fuel and small timber in dry regions, as well as thorns for fencing in agricultural districts; the branches are lopped for cattle fodder, and the leaves are one of the foods of the tasar silkworm. It is cultivated throughout India for its fruit, and the wild fruits are also edible. In some localities the lac insect thrives on the tree. The wood is used for saddle-trees, agricultural implements, and many other purposes, and gives good fuel and charcoal. Silviculturally the tree, in its bushy form, may be of great value in enabling other trees, for example *Bombax malabaricum*, to establish themselves in heavily grazed areas (see under *Bombax malabaricum*, p. 139, and Fig. 61).

DISTRIBUTION AND HABITAT. *Zizyphus Jujuba* is found throughout the greater part of India, either wild or naturalized, ascending to 5,000 ft. in the Himalaya (e.g. on waste land in valleys in the Kumaun hills); it thrives in comparatively dry regions, where it is often gregarious either in the tree form or in the bushy form in grass-lands, its most frequent companion being *Acacia Catechu*. It thrives best on sandy or shingly alluvium and on arable land, but grows on a variety of soils, including laterite, black cotton soil, and even moderately saline soil, while it appears on open waste lands on poor dry ground; it springs up readily on abandoned cultivation in dry localities. On the sandy or gravelly alluvium of dry river-beds it often forms pure crops which in time give place to other species (Fig. 84).

The tree grows wild or naturalized in localities where the absolute maximum shade temperature varies from 100° to over 120° F., the absolute minimum from under 20° to about 55° F., and the normal rainfall from 5 to 90 in. or more.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The old leaves fall about March–April and the new leaves appear at the same time.

The small greenish yellow flowers appear from April to October, the period varying in different localities. The fruits ripen from October to March. In the wild form the drupes are more or less globose, 0.5–0.8 in. long, orange or red when ripe, with a mealy sub-acid pleasantly flavoured pulp in which is the hard furrowed two-celled and two-seeded stone (Fig. 87, *a, b*). The seed has a brown papery testa. The cultivated fruits are larger (about 1.5 in. long) and more ellipsoidal.

In the wild state the tree usually fruits well every year, producing an abundant crop. Tests carried out at Dehra Dun have shown that the seed retains its vitality for at least 2½ years, though the percentage of fertility of old seed is less than that of fresh seed.

GERMINATION (Fig. 87, *c–f*). Epigeous, and similar to that of the teak. The hard stone splits down two sutures which divide it into three parts, namely, the two valves consisting of the outer walls of the cells, and the central wall between the two cells. The cotyledons emerge through the sutures, leaving the seed-coats within the cells, and the radicles push their way downwards; the walls of the stone remain on or in the ground. As a rule two seedlings appear from each stone, one or both of which may become established.



FIG. 87. *Zizyphus Jujuba* -SEEDLING $\times \frac{1}{2}$

a Fruit b -Fruit stone c - f Germination stages g - j.—Development of seedling during first season

THE SEEDLING (Fig. 87).

Roots : primary root long, terete, tapering, wiry : lateral roots moderate in number, fibrous, distributed down main root. *Hypocotyl* distinct from the root, 0.3–0.8 in. long, terete or slightly compressed, cylindrical or tapering up or down, green. *Cotyledons* : petiole 0.4–0.6 in. long, flattened above, glabrous : lamina 0.4–0.6 in. by 0.4–0.6 in., foliaceous, orbicular, apex truncate, base tapering slightly, entire, green, glabrous, 5-veined from base, three veins more prominent than the others. *Stem* erect, terete, wiry, green, tomentose ; internodes 0.4–1.2 in. long. *Leaves* simple, first pair opposite and smaller than the others, subsequent leaves alternate. Stipules up to 0.15 in. long, spinescent. Petiole 0.1–0.2 in. long, channelled above, tomentose. Lamina, first pair 0.7–1.2 in. by 0.6 in., subsequent leaves 1.2–2.5 in. by 0.6–1.2 in., ovate or elliptical, apex acute or rounded, mucronate, base acute or rounded, serrate or nearly entire, glabrous above, sparsely pubescent beneath, prominently 3-veined from the base.

The development of the seedling varies greatly according to the treatment it receives. On loose soil, if weeding and watering is carried out and if the plants grow in full sunlight, the growth is rapid, a maximum length of stem of as much as 2–2½ ft. and 3–4 ft. being attained by the end of the first and second seasons respectively ; the growth is always straggly, and by the end of the third season a thick bushy growth of plants up to 5 ft. high may be obtained under similar favourable conditions. Under ordinary natural conditions the development is much slower, a height of 2 to 5 in. being usually attained by the end of the first season, increasing to about 7 to 14 in. by the end of the second season. The seedling has a long wiry taproot : nursery plants dug up in the second season have been found to have taproots as much as 4 ft. in length. Vigorous nursery-raised plants of the wild variety have been found to flower for the first time in the second season, and to produce an abundant crop of fruit by the end of the third season. In northern India the growth of the seedling ceases about November–December, the leaves commencing to fall in December ; new growth starts in February. Ordinarily the seedlings stand frost well, though severe frost sometimes affects them slightly ; in hot dry weather the new shoots of young plants are apt to dry up, but the seedlings have good power of recovery from such injury.

SILVICULTURAL CHARACTERS. The tree is a light-demander, developing best in open situations ; experiments carried out at Dehra Dun have shown that under even partial shade its development is poorer than in full sunlight, while in the wild state it is typically found in open places. It is decidedly frost-hardy ; in the abnormal frosts of 1905 in northern India, and 1910–11 in the Peninsula, it proved to be one of the hardiest trees. It also stands drought well, as was proved in the severe drought of 1899 and 1900 in central India, when it was unaffected : in the abnormal drought of 1913–14 in central India, however, it is said not to have flowered and fruited, while seedlings of the previous year died in quantity. It has great power of recovery from injury of any kind, including fire, and thrives in grassy tracts which are burnt annually. It is readily browsed by goats and is a good camel fodder ; even in heavily grazed areas, however, the dense prickly clumps protect not only themselves but also other tree seedlings and saplings, enabling them to establish themselves. In its tree form its dense spreading crown affords a considerable degree of shade, killing out grass and other vegetation underneath it. It

coppices and pollards well and produces root-suckers. Measurements made by Mr. C. M. McCrie in Gorakhpur, United Provinces, in 1910 showed an average number of shoots per stool of 2.09, 1.42, and 1.16 for coppice 1, 5, and 7 years old respectively : often, however, it coppices a good deal more freely than this. It is more prone to the attacks of the dodder (*Cuscuta reflexa*, Roxb.) than any other tree, and may frequently be seen covered with this parasite as with a thick yellow net.

NATURAL REPRODUCTION. The wild fruits are greedily devoured by jackals, pigs, bears, and other animals, the stones appearing in quantity in their excreta, and also by peafowl, pigeons, and other birds, whose crops may be found full of fruits swallowed whole ; in this way the seed is scattered widely. If the fruits fall on the ground the outer fleshy portion rots off or dries up and is eaten by white ants or other insects, the hard stone remaining intact. Numerous tests carried out in order to determine the factors which govern the germination of the seed and development of the seedling under natural conditions have shown that fruits or stones which become partially or wholly buried by rain showers or other causes have no difficulty in germinating during the first half of the rainy season, in which case the seedling has little trouble in establishing itself. Fruits or stones which lie on the surface of the ground may germinate to some extent, but in this case the seedlings very often perish before they can establish themselves. The advantage of a loose soil, in which the fruits become readily buried between the time when they fall in the cold or early hot season and the commencement of the monsoon, is thus apparent. Another factor of great importance is that the stones should lie in soil exposed to the sun, since those lying in any but partial shade persistently refuse to germinate, and even those in slight shade show very little tendency to do so. Not only was this observed in various shaded and unshaded plots in the open, but fruits sown in a box kept under shade and regularly watered refused to germinate although fruits otherwise similarly treated but exposed to the sun germinated readily ; eventually the shaded box was placed in the sun, and germination started within a few days. Under natural conditions the fruits or stones lie on the ground throughout the hot weather and germination does not commence till the rainy season. Some of the seed which fails to germinate during the first rains may do so the following year. Abundance of light is essential for the proper development of the young plants ; at Dehra Dun a plot of seedlings which had established themselves under natural conditions and were growing well were in their third year overshadowed by faster growing saplings of other species in an adjoining plot, with the result that their development was checked and several of them were killed.

The abundant fruit crop, the protection afforded to the seeds by the hard stone, the demand for an abundance of sunlight, and the hardness of the seedlings explain to some extent the profusion with which natural reproduction springs up on open lands.

ARTIFICIAL REPRODUCTION. The tree may be raised artificially by direct sowing or by transplanting seedlings or root-suckers. Propagation by cuttings has been tried without success. In the case of direct sowing the fruits, preferably deprived of the fleshy portion or else thoroughly dried, may be sown about a month before the commencement of the rains, either broadcast

on ploughed land or along lines which have been ploughed or dug up; if quick growth is desired during the first few years the latter is preferable, since weeding can be more cheaply and effectively carried out. After sowing, the fruits should be covered with earth to a depth not exceeding $\frac{1}{2}$ in. In Berar the tree has been raised successfully by line sowings in combination with field crops, and this would seem to be the most efficient and economical method of raising it artificially for afforestation purposes, provided that the lines of seedlings are kept free from suppression by the crops.

For transplanting purposes the fruits, deprived of their fleshy covering or well dried, should be sown in seed-beds, either broadcast or in drills, in February or March and covered with earth to a depth of $\frac{1}{2}$ to $\frac{1}{2}$ in. The beds should be situated in the open, fully exposed to the sun, and watering and weeding should be carried out regularly. The seedlings commence to appear as a rule during the hot weather, and continue appearing until the first month or two of the rains. The seedlings may be transplanted either during the first or during the second rainy season, but owing to the long taproot it is preferable to prune the stem down to about 2 in. and the taproot down to about 6 in.; the plants survive this treatment well, and soon commence to shoot up. During the first rains with reasonable care transplanting may be done with unpruned plants; the plants may die down partially, but as a rule they recover next year. The cultivated variety is usually propagated by ring grafting on stocks of the wild form. Plants of the latter, about three years old, are pollarded or coppiced in the cold season, and grafting is carried out on a few of the resulting shoots, the remainder being pruned down. Rings of bark about $\frac{3}{4}$ in. long, including a bud, are taken from the variety which it is desired to propagate and fitted exactly on to corresponding positions on the wild stock from which similar rings of bark have been removed, the whole being bandaged and covered with clay.

RATE OF GROWTH. In open situations the growth is often fast. Gamble's specimens showed 4 to 6 rings per inch of radius, representing a mean annual girth increment of about 1 to 1.6 in. Measurements made in 1910 by Mr. C. M. McCrie in coppice coupes in Gorakhpur, United Provinces, gave the following results :

Age 1 year,	mean height	2 ft. 5 in.
„ 5 years,	„ „	7 ft. 2 in.
„ 7 „ „	„ „	8 ft. 3 in.

Figures recorded in the Punjab Forest Conference Proceedings of 1913-14 of measurements in seven different experimental coupes in the Jhelum and Chenab forest divisions showed an average height-growth during the first season varying from 2 ft. to $5\frac{1}{2}$ ft.; the felling was done at different times from March to July, but the results proved nothing definite as to the best month for coppicing.

2. *Zizyphus Xylopyrus*, Willd. Vern. *Kat-ber*, *bhandar*, *chitena*, *ghat-bor*, Hind.; *Goti*, Hind., Mar., Tel.; *Kottei*, Tam.

A small deciduous tree or large shrub with straggling branches, the branchlets armed with prickles, or often unarmed, especially in the case of old trees or on good soil: bark greyish brown, smooth, or rough with small oblong exfoliating scales. The wood is used for agricultural implements,

fuel, and charcoal. The bark is used for tanning; the fruits are rich in tannin, and are employed for tanning and for dyeing leather black. The leaves are used for fodder. One of the chief uses of the tree, however, is for the propagation of lac. It is a useful tree for clothing certain types of poor dry ground or clay soil where little else will grow.

DISTRIBUTION AND HABITAT. Sub-Himalayan tract and outer hills up to 3,000 ft. from the Sutlej eastwards, Bihar, Chota Nagpur, Rajputana, central and southern India, the Deccan and the Peninsula generally: also in the dry parts of Ceylon. Talbot says it ascends to 4,000 ft. in the Nasik *ghats*, and Bourdillon says it is found everywhere in the sub-alpine deciduous forests of Travancore. It is a very common tree in certain types of dry open deciduous or scrub forests, sometimes on clay soil but also on soil composed of sand and boulders, on hilly, undulating, or flat ground: it is often gregarious, and is frequently associated with *Zizyphus Jujuba* and *Acacia Catechu*, or with *Gardenia turgida*. It occurs frequently on open grass-lands, often forming impenetrable thickets when young, and in the sub-Himalayan tract it springs up in blanks in the sal forests. Fig. 85 shows a typical pure patch. In its natural habitat the absolute maximum shade temperature varies from 100° to 118° F., the absolute minimum from 30° to 60° F., and the rainfall from 20 to 75 in.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The old leaves fall about February–March and the new shoots and leaves appear in April–May, the small clusters of green flowers appearing in the axils of the young leaves on the new shoots from April to June. The young fruits begin to form soon after flowering, and in northern India are full grown but still green by the end of the rains or soon after, becoming fully ripe about January to April next year. The fruit (Fig. 88, *a*) is a globose drupe about 0.75–1 in. in diameter, at first green, turning brown when thoroughly ripe, the fleshy portion dry and mealy, not edible, enclosing a hard stone which is two- or three- (rarely four-) celled, each cell containing one seed, though there are rarely more than two fertile seeds in each fruit. The fruits may hang some time on the tree before falling. The seed within the stone retains its vitality to some extent for 2½ years from the time of ripening, but tests have shown that at any time the proportion of fertile seed is comparatively low, and that it decreases the longer germination is postponed.

GERMINATION (Fig. 88, *b*, *c*). Epigeous. Under natural conditions the seed may germinate either within the stone of the fruit or after it has escaped through the splitting of the stone. The former is perhaps more usual. The stone splits generally in two or three places, portions of the hard shell falling away in the form of valves: as soon as splitting takes place the round green long-stalked leafy cotyledons emerge, leaving the testa inside, and the radicle descends. It is a common occurrence to find two seedlings appearing from one stone, while occasionally three seedlings appear. If the fruit is buried the two cotyledons appear above ground some little distance apart, and the plumule does not emerge for some time after.

THE SEEDLING (Fig. 88).

Roots: primary root long, thin to moderately thick, terete, tapering, wiry: lateral roots numerous, fine, fibrous, distributed down main root. *Hypocotyl* distinct from root but very short, subterranean or only just appear-



FIG. 88. *Zizyphus Xylopyrus*. Seedling $\times \frac{7}{8}$.
 a, fruit; b, c, germination stages; d, e, early development of seedling, first season.

ing on surface of ground. *Cotyledons*: petiole 0.9–1.2 in. long, channelled above, white turning green, minutely pubescent: lamina 0.7–0.9 in. by 0.6–0.7 in., foliaceous, somewhat fleshy, orbicular obovate, truncate or retuse, base sub-cordate, entire, dark green, glabrous, prominently 5-veined from near base, subsidiary veins reticulate. *Stem* erect, terete, somewhat zigzag at nodes, wiry, tomentose; internodes 0.15–0.4 in. long. *Leaves* simple, first pair usually opposite or sub-opposite, smaller than the others, remainder alternate. Petiole 0.1–0.15 in. long, tomentose. Lamina, first pair 0.2–0.3 in. by 0.15 in., subsequent leaves 0.5–0.7 in. by 0.3–0.4 in., ovate, acute, mucronate, serrate, glabrous or slightly pubescent above, pubescent below.

The height-growth of the seedling is slow, but at an early age—often in the first month after germination, when the height is not more than 1–1½ in.—prickly side branches are sent out, and these develop more rapidly than the main stem. By the end of the first season the seedlings are only a few inches high, with numerous side branches up to 6 or 7 in. in length; a long wiry taproot, often 15 in. long by the end of the first season, is produced. The cotyledons persist until the end of the first season, and sometimes through the greater part of the cold weather, before they die off. The subsequent height-growth of the seedling is slow, a height of about 9–15 in. being ordinarily attained by the end of the third season: the branch development, however, is vigorous, and in a few years the young plants form a dense impenetrable thorny thicket. In northern India the leaves of seedlings commence to dry up about November–December and fall from January to March, the plants being leafless until the new shoots and leaves appear from March to May. The leaves are much subject to defoliation by insects. The seedlings are decidedly frost-tender and are apt to die off on damp ground; they withstand drought well. Although weeding stimulates their development they have considerable power of struggling up through a comparatively heavy growth of grass.

SILVICULTURAL CHARACTERS. The tree is a light-demander, growing typically in open situations, but is capable of standing a slight degree of shade. It withstands drought well; in the abnormal drought of 1907 and 1908 in Oudh it suffered slightly, but this was on poor dry soil where most species would have succumbed. It is frost-tender in its younger stages, and is usually considered to be tender to frost in its later stages also. It suffered considerably in the Saharanpur district in the abnormal frost of 1905, though in the neighbouring Lansdowne forest division it is reported to have been one of the last trees affected. It is readily browsed by goats. It has considerable power of recovery from injury, and is thus capable of surviving in areas overrun by fire. It coppices and pollards well. Measurements made in 1910 by Mr. C. M. McCrie in coppice coupes in Gorakhpur, United Provinces, showed an average production of 1.5 to 3 shoots per stool in coppice 5 to 9 years old and 1 shoot per stool in coppice 11 to 15 years old. In grassy tracts the tree tends to kill out the grass underneath it, particularly where it forms thickets.

NATURAL REPRODUCTION. The fruits fall at different times after ripening, during the cold and hot seasons. If they become buried by rain or otherwise, germination frequently takes place during the first rainy season, the stone and the outer covering, if present, splitting as already described. Many fruits, however, lie through the rains and succeeding cold and hot seasons and do not germinate until the second rains, and instances have been noticed where

germination has not taken place until the third rains. Where the fruits lie on the ground for some time the outer soft portion is usually eaten off by white ants or rots off, the hard stone being left, and where the stones lie on the surface of the ground exposed to the sun they often split in the hot weather, the seed escaping and germinating separately. Natural reproduction is often plentiful on grass-lands and other open places; it does not appear under heavy shade. Its establishment is facilitated through the protection offered by the dense straggling thorny growth of the young plants, and their capacity for persisting on poor dry ground, recovering from injury, and struggling through grass.

ARTIFICIAL REPRODUCTION. In order to raise plants in the nursery the stones, divested of their outer covering to hasten germination, should be sown in drills in March or April and covered with earth to a depth of $\frac{1}{4}$ to $\frac{1}{2}$ in. Copious watering stimulates germination, but after germination takes place water should be given more sparingly, otherwise the seedlings are liable to rot. The seed-beds should be fully exposed to the sun. Under these conditions germination ordinarily takes place at different times during the first rains if fresh fruits be used; some fruits may, however, lie without germinating till the second season. If fruit-stones which have lain ungerminated for a year round the trees are collected and sown, germination takes place earlier than in the case of fresh fruits. The seedlings may be transplanted during the first rains. Transplanting during the second rains with pruned stem and roots has not been tried, but it may possibly succeed as in the case of *Z. Jujuba*. This is one of the species which have been raised in direct sowings along with field crops in Berar.

RATE OF GROWTH. The rate of growth of seedling trees is slow, but that of coppice-shoots is fairly rapid. Measurements made in 1910 by Mr. C. M. McCrie, in coppice coupes in Gorakhpur, United Provinces, showed the following rate of growth of *Zizyphus Xylopyrus* as compared with sal in the same coupes:

Zizyphus Xylopyrus: coppice measurements, Gorakhpur, United Provinces.

Age. years.	Mean height.		Mean girth.	
	<i>Zizyphus</i> <i>Xylopyrus</i> . ft.	Sal. ft.	<i>Zizyphus</i> <i>Xylopyrus</i> . in.	Sal. in.
2	4.8	3.0	1.2	—
4	8.2	7.0	2.2	2.0
6	11.0	10.3	3.0	2.9
8	13.2	13.0	3.7	3.8
10	15.2	15.3	4.2	4.8
12	16.8	17.5	4.6	5.8
14	18.3	19.2	5.0	6.7
16	19.3	20.9	5.3	7.5

Measurements made in the Bhandara district, Central Provinces, in 1912–13 showed an average height of coppice-shoots one year old to be 6 ft. 9 in. for *Zizyphus Xylopyrus*, as compared with 7 ft. 5 in. for *Phyllanthus Emblica*, 7 ft. 1 in. for teak, 6 ft. 4 in. for *Acacia Catechu*, and 3 ft. 11 in. for *Buchanania latifolia*. In the Madras Forest Administration Report of 1907–8 it is recorded that coppice-shoots six months old in the Chingleput district had a height of 8 to 15 ft. and a girth of 4 in.

3. *Zizyphus vulgaris*, Lam. Vern. *Singli*, *simli*, Punjab.

A large shrub or small tree with edible fruit, wild in the Punjab and North-West Frontier Province from the Ravi to the Indus, ascending to about 6,000 ft. in the outer Himalaya and growing well on dry gravelly soil; it is cultivated in the Punjab, Kashmir, Baluchistan, and other places as well as in southern Europe, where it has run wild.

In Hazara it is commonly planted round villages in the lower hills up to 6,000 ft., and grows well on dry rocky ground. It has remarkable capacity for producing root-suckers, which form dense thickets, and by means of which it spreads over bare hill-sides (see Fig. 89): for this reason it is an excellent species for afforesting dry or unstable slopes.

An experiment in afforesting a bare hot slope was started in the North-West Frontier Province in 1909-10 by planting root-suckers of this species, about 500 in the rains and a similar number in December: the former all died, but nearly all the latter sprouted, though only about 25 per cent. survived the hot weather. In favourable years planting in the winter would probably be successful. The fragrant flowers appear in May (Hazara).

4. *Zizyphus nummularia*, W. and A. Syn. *Z. microphylla*, Roxb. Vern. *Bal*, *malla*, Pb.; *Jangra*, Sind.

A gregarious prickly shrub of the dry and arid regions of the Punjab, Sind, Baluchistan, Rajputana, and the Indian Peninsula, often flourishing on clay or black cotton soil. The fruits, which ripen in the cold season, are edible, and are devoured by jackals, which spread the seeds. The plant produces root-suckers freely and forms dense thorny clumps.

5. *Zizyphus Oenoplia*, Mill. Syn. *Z. Napeca*, Roxb. Vern. *Makai*, *makoh*, Hind.; *Ironi*, C. P.; *Purgi*, Kan.; *Tawzinwè*, *sudauk*, Burm.

A prickly straggling shrub or climber, common throughout the greater part of India and Burma. The flowers appear from April to July and the fruits ripen in the cold season. This climber is a most troublesome pest in some localities, particularly in the Central Provinces, where it forms dense impenetrable masses, hindering forest operations and preventing the proper development of the trees. Mr. J. W. Best,¹ writing of this pest in the Bhandara division, Central Provinces, notes that it is particularly prevalent wherever heavy grazing has taken place, as other species which are not protected by nature from grazing tend to disappear and make way for this climber. Where on the other hand the forest growth is dense and grazing has been excluded for many years the climber is comparatively rare. Evidence in Chanda points to the fact that the climber has increased enormously owing to fire-protection. Experiments have been undertaken with the view of ascertaining what steps are possible to eradicate it or to keep it under control, and a certain amount of success has been attained in Chanda by cutting it down and then burning the area annually for a series of years; after five years of burning it was found that the pest had visibly decreased except in open places. The climber is a strong light-demander, and any possible means of increasing the density of the growing stock would tend to keep it down. In Bhandara experiments for ascertaining the best means of eradicating it have comprised: (a) cutting the climber at a height of 1 ft. from ground-level and then admitting grazing;

¹ Ind. Forester, xxxv (1909), p. 610.



FIG. 89. *Zizyphus vulgaris*, tree, on right, with dense growth of root-suckers below the road. Hazara, 4,000 ft.

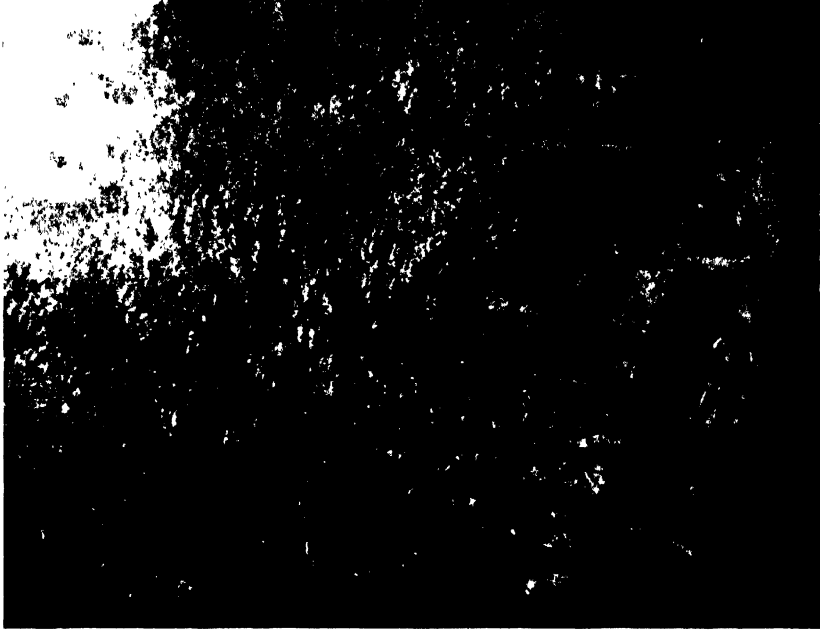


FIG. 90. *Aesculus indica* growing gregariously in a moist ravine 7,500 ft., Kagan Valley, Hazara.



FIG. 91. *Acer caesium* growing gregariously in an open glade at 8,000 ft., Hazara.



FIG. 92. *Schleichera trijuja* trees, Siwaliks, United Provinces.

(b) cutting it and then burning; (c) cutting it, splitting the stump and keeping the split open by means of a stick or stone; (d) cutting it, splitting the stump, and pouring on the exposed surface, particularly on the cambium layer, a solution of quicklime and sulphur in the proportion of 4 oz. of the former to 1 oz. of the latter in 4 lb. of water, the whole being well boiled. According to the latest report available the application of lime, sulphur, and boiling water is said not to have been very successful: splitting the stumps of the cut climber is reported to have given better results.¹

6. *Zizyphus rugosa*, Lam. Syn. *Z. latifolia*, Roxb. Vern. *Suran*, *churna*, *bhand ber*, *dhaura*, Hind.; *Turan*, Mar.; *Churai*, Tam.; *Myaukzi*, Burm.

A scrambling or climbing large shrub or small tree armed with strong hooked prickles, common in many parts of India and Burma. This plant is at times troublesome, but is far less so than *Z. Oenoplia*.

ORDER XX. SAPINDACEAE

An order of considerable interest and importance in Indian forestry.

Genera 1. ACER, Tournef.; 2. DODONAEA, Linn.; 3. AESCULUS, Linn.; 4. SCHLEICHERA, Willd.; 5. SAPINDUS, Linn.

1. ACER, Tournef.

There are about fifteen species of maple in India, all trees of the hills: of these only two are non-Himalayan, one (*A. isolobium*, Kurz) being confined to Burma and the other (*A. niveum*, Blume) to Assam and Burma, while of the Himalayan species two (*A. oblongum*, Wall., and *A. laevigatum*, Wall.) extend to Assam or Manipur, and a third (*A. Thomsoni*, Miq.) to Assam, Manipur, and Burma. Of the Himalayan species three (*A. pentapomicum*, J. L. Stewart, *A. villosum*, Wall., and *A. caesium*, Wall.) occur in the western region; six (*A. Hookeri*, Miq., *A. sikkimense*, Miq., *A. stachyophyllum*, Hiern., *A. Thomsoni*, Miq., *A. Papilio*, King, and *A. Campbellii*, Hook. f. and Thoms.) in the eastern region: and four (*A. oblongum*, Wall., *A. laevigatum*, Wall., *A. caudatum*, Wall., and *A. pictum*, Thunb.) in both regions. Hitherto the Indian maples have not possessed the economic importance of those of most other countries in which maples are found. This is not due to any inferiority in the quality of the wood, for according to Gamble the structure of the wood of all maples, Indian included, is very uniform, and most if not all Indian species possess the handsome silver-grain characteristic of maple wood in general. That the wood of Indian maples has so far been restricted almost entirely to local use is due mainly to the fact that the trees are found chiefly in mountainous country from which extraction is difficult, that the wood is not durable enough for general construction on the plains, and that the demand for woods of its class for joinery or ornamental work can be met by other woods in more accessible regions. Locally the wood of maples is used for planking, tea-boxes, and construction, and for turning into drinking-cups and other utensils. With improvements in methods of extraction and with the development of wider markets the Himalayan maples may yet become of greater economic importance than is the case at present, in which event more attention will have to be paid to their silvicultural study than has

¹ Forest Report, C. P., 1916-17.

been found necessary in the past. Silviculturally some of the maples are of local importance in restocking open spaces, as their reproduction by seed is usually good. They are easily raised from seed sown in nursery beds in the spring, transplanting being best done in the winter. The maples as a rule coppice well and produce root-suckers; they are fairly immune from damage by browsing.

Species 1. *A. oblongum*, Wall.; 2. *A. laevigatum*, Wall.; 3. *A. pentapomicum*, J. L. Stewart; 4. *A. caesium*, Wall.; 5. *A. villosum*, Wall.; 6. *A. pictum*, Thunb.; 7. *A. Campbellii*, Hook. f. and Thoms.; 8. *A. sikkimense*, Miq.

1. *Acer oblongum*, Wall. Vern. *Pangoi*, *parpat*, *kirmola*, W. Him.

A moderate-sized tree of the outer Himalaya and valleys from the Jhelum to Bhutan, ascending to 6,500 ft., Assam, Manipur. It is essentially a low-level species, being found both on the outer hill slopes of the Himalaya, for example below Mussoorie, and in ravines or moist valleys, as along the banks of the Kotri river in the United Provinces at 2,000 ft., and in some parts of the Dehra Dun valley below 2,000 ft. The leaf differs from the ordinary type of maple leaf in not being lobed, but oblong lanceolate and entire. The tree is never quite leafless; the new shoots and leaves, which are glossy, reddish brown or pale yellowish green, appear in March–April, and the old leaves fall soon after. The flowers appear with the young leaves, and the fruits ripen next cold season, hanging some time on the trees: the winged fruit is the usual double samara characteristic of maples in general. The tree is sometimes planted for ornament. It is easily raised from seed sown in beds about March, the seedlings being pricked out in the nursery during the first rains and transplanted either in the rains following or in the cold season. The seedlings bear transplanting well. It is unnecessary to prune the roots and stem except in the case of large plants: they survive the operation, but subsequent growth for a year or two is not so rapid as in the case of unpruned plants. The growth of young plants is fairly rapid. Plants raised at Dehra Dun showed the following height-growth during the first four seasons:

1st season	.	.	.	height 6–12 in.
2nd season	.	.	.	maximum height 3 ft. 6 in.
3rd season	.	.	.	maximum height 5 ft. 9 in.
4th season	.	.	.	height 2 ft. 1 in. to 10 ft. 7 in.

On stiff ground the plants develop badly; good drainage and porous soil are required to promote the best growth. Weeding also has a marked effect on the development of the seedlings and saplings. The tree coppices vigorously, the shoots growing rapidly. Gamble's specimens showed the growth of the tree to be moderate, namely 7 rings per inch of radius or a mean annual girth increment of 0.9 in.

2. *Acer laevigatum*, Wall. Vern. *Putli*, Nep.

A tree larger than *A. oblongum*, but with leaves somewhat similar in shape. It occurs in the Himalaya from the Jumna eastwards at 5,000–9,000 ft., being commoner in the east than in the west; also in the Khasi hills.

3. *Acer pentapomicum*, J. L. Stewart. Vern. *Trekhan*, *teon*, W. Him.

A small or moderate-sized tree of the western Himalaya in the Punjab and Kashmir, from 2,500 to 7,000 ft. in the inner dry valleys, where it is

almost gregarious in hot dry situations associated with *Quercus Ilex* and *Frazinus xanthoxyloides*. In the Jhelum valley it descends below 2,000 ft. It is common on the banks of dry ravines at low elevations in the Hazara district.

4. *Acer caesium*, Wall. Vern. *Barakainju*, *trekhan*, *mandar*, W. Him.

A large tree, attaining a girth of 10 ft. or more : the largest maple of the western Himalaya. Leaves 5-lobed, broader than long, usually glaucous beneath.

DISTRIBUTION AND HABITAT. Western Himalaya from Nepal westwards, chiefly at 7,000–10,000 ft. but occasionally descending to 4,000 and ascending to 12,000 ft. This is the commonest maple of the western Himalaya, and is very typical of grazing grounds and open glades, where it is often more or less gregarious (see Fig. 91). It is particularly common in the forests of the Galis in Hazara, where it is in many places the most abundant broad-leaved species ; here it is associated with *Abies Pindrow*, *Pinus excelsa*, *Taxus baccata*, *Aesculus indica*, *Ulmus Wallichiana*, *Prunus Padus*, and other trees, and often occurs in gregarious patches.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The tree is leafless in the winter, the new leaves, which are red at first, appearing from March to May. The flowers appear with the young leaves. The fruits ripen from July to October. The double samara (Fig. 93, a) is 1.5–2 in. or more in length.

GERMINATION (Fig. 93, b, c). Epigeous. The radicle emerges from the end of the samara opposite the wing and descends. The hypocotyl elongates, raising above ground the cotyledons enclosed in the samara ; the latter falls to the ground as the cotyledons unfold.

THE SEEDLING (Fig. 93).

Roots : primary root at first moderately long, lengthening considerably later, terete, tapering, thick after the first season, at first wiry, afterwards becoming woody : lateral roots at first moderate in number and length, afterwards numerous, fibrous, distributed down the main root and most numerous towards its extremity. *Hypocotyl* 1.2–2 in. long, fusiform or tapering upwards, glabrous, tender and green or red when young, later becoming woody and greenish brown. *Cotyledons* sub-sessile, 1.1–2.2 in. by 0.3–0.5 in., foliaceous, somewhat fleshy, oblong lanceolate or ovate lanceolate, acute, base tapering, entire, green, glabrous, darker above than beneath ; five parallel veins visible on under surface, the centre three more distinct than the outer two. *Leaves* simple, opposite, exstipulate. First pair, petiole 0.4–0.7 in. long, lamina 1–2.3 in. by 0.6–1.8 in., ovate, acuminate, base cordate, serrate, lobes hardly commenced forming, glabrous, green above, glaucous beneath. Subsequent leaves increasing in size and becoming more distinctly lobed ; by second season regularly 5-lobed and palmately 5-veined ; by third season petiole up to 2 in. long, green or reddish, lamina up to 5 in. by 5 in., central lobe acuminate, remaining lobes acuminate or acute, serrate, glabrous, paler beneath than above.

During the first two or three years the growth of the seedling amounts to only a few inches a year, but from the fourth season onwards it is more rapid, the annual growth being up to 1 ft. or more. Seedlings four years old average about 2 ft. in height and have long stout taproots. For its best development the seedling requires a porous soil free from weed-growth. It stands moderate shade for a time, but once established it requires an abundance of light. On dry ground the seedlings tend to die of drought in the first season.

SILVICULTURAL CHARACTERS. This maple is more light-demanding than *A. pictum*, with which it is sometimes associated. In youth it stands moderate but not heavy shade, while subsequently it thrives best with complete overhead

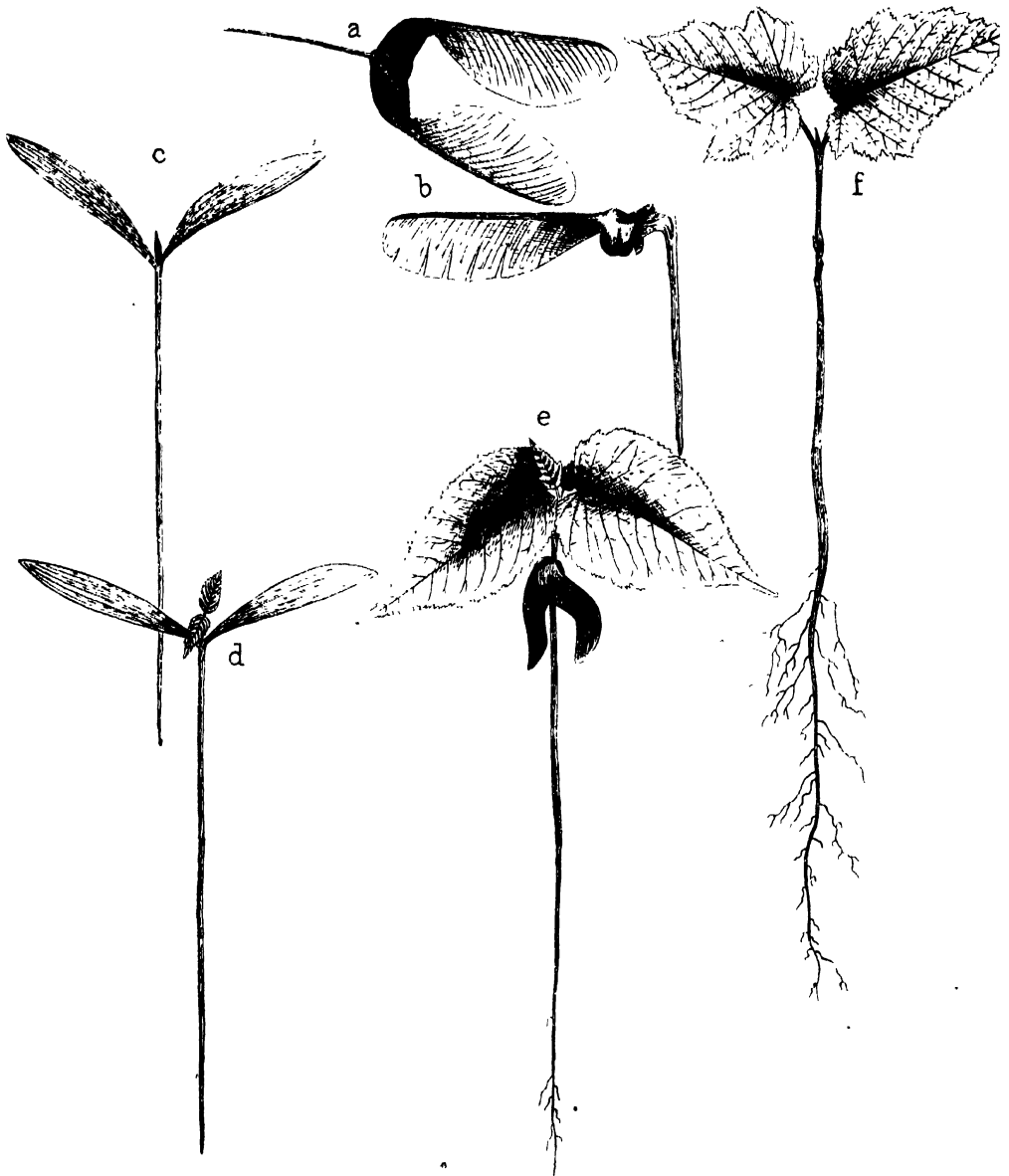


FIG. 93. *Acer caesium*. Seedling $\times \frac{5}{8}$.

a, fruit; *b*, *c*, germination stages; *d*, *e*, development of seedling during first season; *f*, seedling early in second season.

light. It is not readily browsed, and in its natural habitat is frost-hardy. It produces root-suckers.

NATURAL REPRODUCTION. The seed lies on the ground through the winter and germinates next spring, about April, when seedlings in all stages of germination may be found in quantity in the neighbourhood of seed-bearers.

Natural reproduction springs up in quantity on newly exposed and especially porous ground, and in places where landslips have occurred thickets of young maple may be found establishing themselves. The young plants dislike heavy weed-growth, and where this is prevalent reproduction fails. On open grazing grounds young seedlings may often be found in large quantities in the late spring or early summer, particularly where the soil is bare and loose ; here the seed germinates shortly after the melting of the snow. Such places are often exposed to drought during the ensuing dry weather, and numerous seedlings perish from this cause, while grazing destroys most of the remainder, although in sheltered situations some succeed in establishing themselves.

ARTIFICIAL REPRODUCTION. Seed should be sown in seed-beds of porous soil about February or March. Germination takes place as a rule in about two to four weeks. The beds should be regularly watered in dry weather and kept free of weeds. The seedlings, which may require pricking out in the nursery, will be ready for planting out in the winter at the end of the second or third season according to size. Direct sowing has not been tried, but it would probably succeed on landslips, abandoned cultivation, or other places where the soil has been recently exposed.

RATE OF GROWTH. The growth is slow, Gamble's specimens showing 9 to 31 rings per inch of radius, or a mean annual girth increment of 0·2 to 0·7 in.

5. *Acer villosum*, Wall. Vern. *Kainju*, W. Him.

A large tree of the western Himalaya at 7,000–9,000 ft., much less common than *A. caesium* ; leafless in the winter.

6. *Acer pictum*, Thunb. Syn. *A. cultratum*, Wall. Vern. *Kainchli*, *kil-pattar*, W. Him.

A handsome moderate-sized tree, found throughout the Himalaya from the Indus to Bhutan, at 4,000–9,000 ft. Leafless in the winter, the leaves turning red before falling. It is more shade-bearing than *A. caesium*.

7. *Acer Campbellii*, Hook. f. and Th.

The commonest maple of the eastern Himalaya, occurring at 7,000–10,000 ft. ; a large deciduous tree. Gamble (*Darjeeling List*) says the seedlings come up very freely self-sown, provided there is not much shade.

8. *Acer sikkimense*, Miq.

A moderate-sized tree, common in the eastern Himalaya, particularly on open spaces at 7,000–9,000 ft.

2. DODONAEA, Linn.

Dodonaea viscosa, Linn. Syn. *D. Burmanniana*, DC. Vern. *Sanatta*. Ph. ; *Mehndi*, *banderu*, C. P. ; *Lutchmi*, Mar. ; *Bundurgi*, Kan. ; *Virali*, Tam.

A gregarious evergreen shrub or small tree, the young shoots viscid with a yellow resin. It is locally abundant in the dry parts of the western Himalaya from the plains up to 4,500 ft., occurring sporadically up to 6,500 ft. on hot aspects (e. g. Simla hills), Sind, Baluchistan, and the Indian Peninsula. It is planted as a hedge plant throughout the greater part of India. Besides yielding good fuel of the smaller dimensions it is a useful plant for sowing up bare slopes in suitable localities. In the *Pinus longifolia* forests of the outer Punjab hills, and in the dry miscellaneous forests below them, it is a very common undergrowth species, covering considerable areas. It is abundant

over large tracts in the Deccan and in many of the drier parts of southern India, where it flourishes from the sea-coast up to 8,000 ft. in the hills, sometimes attaining the size of a small tree. Kurz says it grows on the sandy shores of Tenasserim from Amherst to Mergui; also on Narcondam island, Andamans. Regarding its occurrence in the southern forest circle, Central Provinces, Haines¹ says: 'Generally speaking it avoids trap and favours sandstone. In the Sonawani range (Balaghat) it is found on ridges of white clay schist, but is local. In Chanda it is very common and is also found there on kunker soils. In Raipur it is rare, and has not yet been noted in Nagpur-Wardha, Bhandara, or Bilaspur. It reappears on the sandstones of the Pachmarhi hills (Northern Circle).' The plant is dioecious. The season of flowering and fruiting appears to vary in different localities, the fruiting as a rule taking place in the cold and early hot season. In the outer Himalaya it flowers from January to March and the fruits ripen in the hot season, chiefly in May and June. The fruits hang in large quantities. The seeds are about 0.1 in. in diameter, nearly globose, slightly flattened, black with a hard testa; about 3,000 weigh 1 oz. The plant is usually said not to coppice: it certainly sends up numerous small shoots when cut, but possibly these do not persist. It reproduces abundantly from seed, and this, together with its capacity for growing on poor dry soils and its immunity from browsing, explains its abundance over considerable areas. It is very sensitive to fire, and is frequently killed outright when burnt, its resinous twigs burning readily.

3. AESCULUS, Linn.

Species 1. *A. indica*, Colebr.; 2. *A. punduana*, Wall.

1. *Aesculus indica*, Colebr. Syn. *Pavia indica*, Wall. Indian horse-chestnut. Vern. *Bankhor*, *pangar*, *kandar*, *gun*, *pu*, W. Him.; *Kakra*, *hán*, Kashmir; *Torjaga*, N.-W. Frontier.

A large handsome deciduous tree with a large spreading crown, drooping branches, and digitate leaves, much resembling the European horse-chestnut. Bark grey and smooth in young trees, darker and exfoliating in irregular rectangular scales in middle-aged or older trees, and in old trees often exfoliating in long narrow strips sometimes 2 ft. long, the lower extremities of which are free and the upper extremities attached to the tree, giving the bole a curious appearance as if covered with some thatching material.

Wood pale pink, soft, used for planking, boxes, and turning into cups, plates, &c. The tree attains a large size, a height of 100 ft. and a girth of 12 ft. or more being not uncommon in favourable localities.

DISTRIBUTION AND HABITAT. Western Himalaya from Nepal westwards, at 4,000–9,000 ft. usually in moist shady ravines on rich soil: frequent on northerly aspects. In moist depressions and ravines running down the hill-sides it often forms gregarious patches of varying extent (see Fig. 90). It is particularly common in the forests of Hazara, where it is associated with walnut, maple, bird-cherry, and other broad-leaved species as well as with silver fir, spruce, yew, deodar, and blue pine, though it usually occupies the depressions and moister situations, while the conifers occupy the intervening spurs. It is often planted for ornament in the hills. In its natural habitat

¹ Ind. Forester, xxxix (1913), p. 68.



FIG. 94. *Aesculus indica*—SEEDLING $\times \frac{3}{8}$

Seed b-g--Germination stages (f shows cotyledons, with testa removed) h Seedling in first season

the absolute maximum shade temperature ordinarily varies from 80° to 102° F., the absolute minimum from 25° to 10° F. or perhaps lower, and the normal rainfall from 40 to 100 in. or more.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The leaves turn various shades of yellow or golden brown in September–October, and fall from October to early December. The tree often assumes a beautiful colouring in the autumn. From December to April the trees are leafless. The new leaves appear in April, the gummy outer scales and membranous inner scales of the winter buds falling with the sprouting of the new shoots. The new leaves are of a coppery red colour, and with them appear the flower buds. The large upright thyrsoïd panicles of showy white flowers, tinged with red and yellow, appear from April to June, at which time the tree is extremely handsome. The fruit forms rapidly, growing in size and weight until it becomes pendulous, the stalks elongating. The fruit is an ovoid one- to three-celled leathery capsule 1.5–2 in. long, smooth, and not echinate as in the European species, containing one to three seeds 1–1.6 in. in diameter with a dark brown smooth shining fairly hard testa and a hilum about 0.5 in. in diameter (Fig. 94, *a*). About sixteen to twenty seeds weigh 1 lb. The capsules open and the seeds fall to the ground in October–November.

GERMINATION (Fig. 94, *b–g*). Hypogeous. It commences with the bursting of the testa and the elongation of the cotyledonary petioles, the thick whitish radicle emerging at an early stage and developing rapidly into a stout vigorous taproot : as the cotyledonary petioles further elongate the plumule extricates itself, the base of the young shoot being enveloped by a short tube formed by the united bases of these petioles. This elongation of the cotyledonary petioles in order to push the radicle as quickly as possible into the soil, and the rapid development of the taproot, which are also characteristic of several of the hill oaks, are contrivances for assisting the establishment of the seedling.

THE SEEDLING (Fig. 94).

Roots : primary root long, thick, almost fleshy, terete or slightly compressed, tapering, tomentose : lateral roots numerous, moderately long, thick, tomentose, distributed down main root. *Hypocotyl* not distinguishable, subterranean. *Cotyledons* : petiole 1.2–2.2 in. long, 0.4 in. broad, fleshy, flattened, pink, curved to side of stem, more or less united at the base into a short tube : laminae 1.2–1.6 in. in diameter, hemispherical, fleshy, closely cohering, outer surface rounded and depressed, inner flattened in contact. *Stem* arched during germination, soon becoming erect, slightly compressed, red turning reddish green, dotted with small whitish lenticels, glabrous or young parts minutely tomentose ; internodes 3–6 in. or more in length. *Leaves* compound, opposite, exstipulate : first pair often rudimentary, trifoliate, petiole 1 in. long or less, flattened above, expanded at base, leaflets 0.3 in. long or less, linear lanceolate : second pair 5-foliate, rarely 3- or 4-foliate, petiole 0.8–1 in. long, flattened above, expanded at base, usually red, glabrous, leaflets up to 2 in. by 0.4 in., lanceolate or oblanceolate, acuminate, serrate, glabrous, venation arcuate ; subsequent leaves of first season 5-, 6-, or 7-foliate, similar in shape to second pair but becoming successively larger with number of leaflets increasing. Young leaves red, turning green after expanding.

The early development of the seedling is very rapid. The stout somewhat fleshy taproot may reach a length of 6–7 in. before the plumule emerges, but as soon as the latter appears the stem shoots up rapidly, a height of 1 ft. or

more being reached within two months, the stout taproot being 1 ft. or more in length at that time. By the end of the first season a height of 2 ft. or more may be attained. The seed remains attached to the base of the plant throughout the greater part of the first season, the thick fleshy cotyledons supplying nutriment to the young plant. The seedling requires a damp situation for its best growth ; in dry hot places it develops poorly and may die off. Although seedlings will persist under moderate shade for a time their growth is slow ; for their best development a fair amount of light is required. A seedling only 18 in. high growing under somewhat heavy shade in Hazara was found to have fifteen annual rings. Seedlings are very readily browsed.

SILVICULTURAL CHARACTERS. The tree is a moderate light-demander, requiring a moist and slightly shady place for its early development with more light subsequently, though a considerable amount of moisture in the soil is always necessary to promote the best growth : if planted on dry hill-sides it remains stunted and unhealthy. It coppices well up to a considerable size, stumps up to 10 ft. in girth having been found to give a plentiful crop of shoots. It also produces root-suckers, particularly if the roots are cut. The tree sometimes has a pronounced twist from right to left.

NATURAL REPRODUCTION. The seeds fall in October–November, and their weight and their smooth rounded form cause them to roll into depressions, where they become covered with leaves and earth and are protected to some extent from monkeys and other animals which eat them ; there they pass the winter, often under snow. Germination takes place in the following spring, commencing about April : in the case of seed lying in moist places and covered with leaves and débris, germination is successful, and the seedling rapidly establishes itself, but in drier and more open places the radicles tend to die off before germination is complete, and here the young plants are seldom able to survive. The horse-chestnut can hardly be called a gregarious tree except over restricted areas, but natural reproduction often springs up in quantity in moist ravines where conditions are favourable to successful germination and development. On moist cool slopes where the soil has been exposed by small landslips, natural seedlings are sometimes found in large numbers in loose soil among stones and boulders, which hold up the seeds.

ARTIFICIAL REPRODUCTION. The tree is not considered valuable enough to grow in forest plantations, but it is often cultivated for ornament. There is little difficulty in growing it provided dry situations exposed to a hot sun are avoided. The seeds should be collected when they ripen, in October or November, and either sown immediately after collection or stored in dry earth and sown early next year. Sowing should be done in seed-beds with good soil in a cool shady situation, the seeds being placed 6 in. apart in drills 1 ft. apart and covered with about 2 in. of earth. The beds should be weeded regularly and the soil kept loose ; little watering is required. If desired the seedlings may be planted out during the first winter, but if larger plants are required they should be transplanted in nursery beds during the first winter 1 ft. apart in lines 18 in. apart, the beds being kept weeded but not watered : they should be finally transplanted during the following winter, it being unnecessary to retain earth round the roots in transplanting.

2. *Aesculus punduana*, Wall. Syn. *A. assamica*, Griff.

A tree of the Duars, Assam, and Burma, somewhat resembling *A. indica*. It is found in moist situations, especially along the banks of streams, and is very handsome with its dense spreading crown of rich green foliage, particularly when covered with the erect panicles of white flowers, which appear in February–March.

4. SCHLEICHERA, Willd.

Schleichera trijuga, Willd. Vern. *Kusam*, Hind. ; *Sagada*, Kan. ; *Pava*, *puvan*, Tam. ; *Gyo*, Burm. (Fig. 92.)

A large deciduous (nearly evergreen) tree with a fluted comparatively short trunk and a shady spreading crown. Leaves paripinnate with two to four pairs of leaflets 2–10 in. long. Bark grey, red inside, exfoliating in irregular plates. Wood very hard, reddish brown, used for oil and sugar mills, rice pounders, agricultural implements, and other purposes. The fruit is edible and the seeds yield an oil of some value. One of the chief uses of the tree is for the propagation of lac, the quality of which is considered better than that produced on any other tree. Silviculturally the tree is useful as affording shade and protection to the soil, since it puts out its young foliage early in the hot season and gives good shade during the hottest time of the year : in the teak forests of Java it is on this account considered one of the best species to mix with the teak.

DISTRIBUTION AND HABITAT. Sub-Himalayan tract from the Sutlej to Nepal, Chota Nagpur, Central India and the Peninsula generally, and throughout Burma ; apparently absent from Assam. The tree is typical of mixed deciduous forests, often of a somewhat dry type. In the sub-Himalayan tract and outer hills it is common on well-drained boulder deposits, often occurring in quantity along the sides of ravines or along the high banks marking the edges of terraces. It is common on the south side of the Siwalik range, often on the sides of ravines on sandstone or on boulder beds. In the Central Provinces it occurs scattered in mixed forest, chiefly near the banks of streams : it is common in the Raipur district. In Burma it is common both in the upper mixed forests of the low hills and in the lower mixed forests of the plains, its spreading crown often taking up a considerable amount of room in the crop : in the lower mixed forests it grows on good alluvial loam. In general it thrives best on a light well-drained gravelly or loamy soil. In its natural habitat the absolute maximum shade temperature varies from 100° to 118° F., the absolute minimum from 30° to 60° F., and the normal rainfall from 30 to 100 in. or more.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The old leaves begin to fall from December to February, turning golden yellow prior to falling, and the tree is leafless for a short time or hardly at all ; the new foliage, which is of various shades of red, turning light green and then dark green, appears in March–April. The racemes of greenish yellow flowers appear with the young leaves, some trees producing only male flowers. The fruits ripen in June–July, and quickly fall to the ground : they are globose or ovoid, 0.5–1 in. long by 0.45–0.7 in. in diameter, abruptly tapering to a point, sometimes slightly echinate, toughly coriaceous when fresh, becoming hard and brittle on drying, one-celled and one- or two-seeded (Fig. 95, *a*). The seeds are 0.4–0.6 in. by

0.35–0.5 in., irregularly ellipsoidal, slightly compressed, very oily, with a thick brown testa, enveloped when fresh in a succulent arillus of pleasantly acid taste: about forty to fifty seeds weigh 1 oz. The seed does not retain its vitality long.

GERMINATION (Fig. 95, *b–d*). Epigeous. The shell of the fruit cracks or is eaten by white ants soon after falling, the testa of the seed bursts, and the radicle emerges. The hypocotyl arches slightly, soon straightening and raising the fleshy unequal cotyledons above ground; the testa is sometimes left underground and sometimes carried up over the cotyledons, falling when these expand.

THE SEEDLING (Fig. 95).

Roots: primary root very long, moderately thick, terete, tapering, wiry, becoming woody, brown: lateral roots numerous, short to moderately long, fibrous, distributed down main root. **Hypocotyl** distinct from the root, 1.2–2.2 in. long, elliptical in section, fusiform or tapering slightly upwards, pink, tomentose in upper part, glabrescent in lower. **Cotyledons**: petiole up to 0.1 in. long, thick, flattened above: laminae one longer than the other, the apex of the former overlapping that of the latter during germination, the longer about 1 in. by 0.3 in., the shorter about 0.8 in. by 0.3 in., thick, fleshy, oblong, apex rounded, base sagittate or truncate, outer surface convex, inner concave, pale yellow or pink, glabrous. **Stem** erect, terete, green or pink, tomentose. **Leaves** compound, exstipulate, first pair or sometimes more than one pair opposite, subsequent leaves alternate, tender and usually pink to deep red when young, afterwards turning coriaceous and dark green. First pair 3-foliate, rarely 2-foliate; common petiole 0.5–0.7 in. long, terete, tomentose; terminal leaflet with petiolule 0.2–0.3 in. long, lamina 2–3.5 in. by 0.5–1 in., elliptical lanceolate, acute or shortly acuminate, base acute, margins entire or wavy, glabrous above or puberulous when young, pubescent on veins of lower surface and round margins, venation arcuate; lateral leaflets subsessile or very shortly petiolate, 1.8–2.8 in. by 0.4–0.9 in., unequally elliptical lanceolate, acute or shortly acuminate, base semicordate, margins &c. as in terminal leaflet. Subsequent leaves of first season normally 4-foliate, the rachis ending in a small bristle; terminal pair of leaflets much larger than lateral pair, the former up to 5 in., the latter up to 2 in. long. In the second year 5- or 6-foliate leaves are produced.

During the first season the growth of the seedling is comparatively slow, a maximum height of 3 to 6 in. being attained by the end of the year. The subsequent development depends largely on whether the plants are freed from weeds or not. In various experimental plots at Dehra Dun, by the end of the second season the heights attained were as follows:

- | | |
|--|-----------|
| (1) Weeded irrigated plots | 2½–28 in. |
| (2) Unweeded irrigated plots | 2–8 in. |
| (3) Weeded unirrigated plots | 3–13 in. |
| (4) Unweeded unirrigated plots | 1½–5 in. |

By the end of the third season in unirrigated plots, irrigation having been abandoned, the height varied from 2 to 7 ft. where weeding was carried out, the plants being stout and vigorous, and was only 2 to 6 in. where weeding was not carried out. In northern India the growth of seedlings ceases for a time during the cold season; the leaves fall in January–February and the red new shoots and young leaves appear in February–March.



FIG. 95. *Schleicheria trijuga*—SEEDLING $\times \frac{3}{8}$

a - Fruit b d Germination stages e - g—Development of seedling during first season
h, i—Development of vigorous seedling to end of first season

SILVICULTURAL CHARACTERS. *Schleichera trijuga* is a shade-bearer and a hardy tree as regards both frost and drought. In the abnormal droughts of 1899–1900 in the Indian Peninsula, and of 1907–8 in Oudh, it was unaffected. In its earlier stages it is very subject to damage by grazing, as cattle eat the young leaves readily. It produces root-suckers freely. Its coppicing power, though at times vigorous, appears to vary somewhat. Measurements in coppice coupes in the Rangoon division, Burma, showed an average of as many as 14 shoots per stool : on the other hand, Mr. A. E. Osmaston records the fact that of five trees coppiced in Gorakhpur, United Provinces, in 1909–10 not one produced any coppice-shoots. Other figures are given below under ‘rate of growth’. Measurements in 1910 by Mr. McCrie in Gorakhpur showed 1 to 3 shoots per stool in coupes one to sixteen years old, while Mr. H. A. Gass in South Canara found as many as 18 shoots three years old on a stool. It pollards well, a fact which closely affects the cultivation of lac. Trees producing good crops of lac are those with a full round crown and not those which have grown up in a crowded crop and have badly developed crowns. In order to prepare trees for lac cultivation the crop should be opened out to some extent around them, lanky trees with badly developed crowns being heavily pollarded to induce a full crown, and any badly developed lower branches being pruned off. In the Raipur district of the Central Provinces, where lac is cultivated on this tree, two crops are obtained in the year, the *katki* crop (December–January) and the *bathri* crop (July–August) ; the former is usually the better. The quantity of lac produced per tree varies greatly with the size of the crown and the vigour of the shoots. An average of 30 to 40 lb. per tree per annum for the two crops is ordinarily reckoned on : trees have been known to produce as much as 180 lb. per annum. The yield of lac from *Butea frondosa* is considerably less.

NATURAL REPRODUCTION. The fruits fall towards the end of the hot season or in the beginning of the rains ; the pulp and shell of the fruit soon dry up, the latter cracking or becoming eaten by white ants and the seed being washed out by heavy rain. Under natural conditions germination and the establishment of the seedling appear to depend largely on the seed becoming quickly buried in earth and débris ; if this happens germination takes place not long after the fall of the fruit, but large quantities of seed perish when lying on the surface of the ground exposed to the sun. The subsequent development of the seedling, as already explained, depends on freedom from weed-growth. Much of the natural reproduction seen in the forest consists of root-suckers.

ARTIFICIAL REPRODUCTION. Experiments carried out at Dehra Dun have shown that the transplanting of nursery-raised seedlings during the second rains is attended with a good deal of failure owing to the length of the taproot. Pruning the root and stem has not yet been tried, but possibly this may result in greater success. Transplanting in the first rains is not to be recommended owing to the small size of the plants, and even at this stage the seedlings require great care in transplanting. Good results have been attained by direct sowings in well-loosened soil, the seeds being covered with earth ; regular weeding for the first few years is essential. It is probable that line sowings in conjunction with the raising of field crops would prove successful.

In any form of sowing the seed requires to be sown and covered as soon after collection as possible, and grazing has to be excluded until the saplings are out of reach of cattle.

RATE OF GROWTH. The growth of seedling trees is believed to be slow to moderate, though reliable measurements are not available. The growth of coppice-shoots is fast during the first few years, becoming slower afterwards. In 1898 Mr. H. A. Gass in South Canara measured shoots three years old with a height of 16 ft., and in 1911 I measured in Gonda, United Provinces, shoots one year old with an average height of 7 ft.

The following are the results of coppice measurements in 1910 by Mr. C. M. McCrie in Gorakhpur, United Provinces, the growth of *Schleichera* being compared with that of sal :

Schleichera trijuga : coppice measurements, Gorakhpur.

Age. years.	Mean height.		Mean girth.	
	<i>Schleichera</i> . ft.	Sal. ft.	<i>Schleichera</i> . in.	Sal. in.
2	4.3	3.0	—	—
4	7.2	7.0	2.2	2.0
6	9.6	10.3	2.9	2.9
7	11.8	13.0	3.6	3.8
10	13.7	15.3	4.3	4.8
12	15.2	17.5	4.8	5.8
14	16.5	19.2	5.3	6.7
16	17.5	20.9	5.6	7.5

5. SAPINDUS, Linn.

Species 1. *S. detergens*, Roxb.; 2. *S. laurifolius*, Vahl.

1. *Sapindus detergens*, Roxb. Syn. *S. Mukorossi*, Gaertn. Soapnut of northern India. Vern. *Ritha*, *thali*, Hind.

A large handsome deciduous tree with paripinnate leaves 8–18 in. long, with five to ten pairs of leaflets; leaves somewhat resembling those of *Cedrela Toona*. Bark brown, exfoliating in irregular woody scales. It is not an important forest tree, but is frequently cultivated for ornament or for the sake of its fruits, the pulp of which is used as a substitute for soap.

DISTRIBUTION. Possibly indigenous in the western Himalaya from the Sutlej eastward up to 4,000 ft., Assam. Much cultivated in northern India up to 5,000 ft. in the Himalaya.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The leaves turn a rich yellow about December, falling in December–January. The trees are leafless from then until March or April, when the new leaves appear. The panicles of white or purplish flowers appear in May–June, and the fruits commence to ripen in November, remaining on the trees till January or later, the bunches of round fruits being conspicuous when the tree is leafless. The fruit (Fig. 96, *a*) is a one-seeded globose drupe, usually solitary, sometimes two drupels together, about 0.75 in. in diameter, smooth, with yellow flesh when ripennig, the flesh drying into a light brown, somewhat translucent saponaceous substance with a wrinkled surface. The seeds (Fig. 96, *b*) are smooth, black, nearly globose, about 0.5 in. long, very hard. About 350 to 400 weigh 1 lb. Tests have shown that the seed retains its vitality for one year and to a slight extent for two years.

GERMINATION (Fig. 96, c-g). Epigeous. It commences by the splitting of the hard covering of the seed and the emergence of the radicle, which grows rapidly downwards, the hypocotyl arching slightly until the fleshy cotyledons extricate themselves, after which the young shoot develops rapidly.

THE SEEDLING (Fig. 96).

Roots : primary root moderately long, thick, terete, tapering, whitish when young : lateral roots numerous, fibrous, distributed down main root. *Hypocotyl* distinct from and thicker than root, 1.2-1.6 in. long, thick, terete below, slightly compressed above, fusiform or tapering slightly upwards, green, glabrescent. *Cotyledons* : petiole under 0.1 in. long, thick, fleshy, flattened : lamina 0.8-1.2 in. by 0.4-0.5 in., thick, fleshy, ovate lanceolate, acute, entire, pale yellow at first, turning dark green. *Stem* erect, compressed, green, pubescent. *Leaves* compound, paripinnate or imparipinnate, exstipulate, first pair opposite, rarely alternate, subsequent leaves alternate. *Rachis* 2-3 in. long in earliest leaves, longer in subsequent leaves, winged. *Leaflets* opposite or sub-opposite, usually three pairs with a terminal leaflet in the first leaf, increasing later in first season to about five pairs with or without a terminal leaflet, 1-3 in. by 0.25-0.8 in., lanceolate, acuminate, entire, sub-coriaceous ; young leaves finely pubescent, older leaves glabrous.

Where weeding and watering are carried out the growth of the seedling is rapid, a height of 6-9 in. being reached by the end of the first season and a height of 2-4 ft. by the end of the second season, by which time the taproot may attain a length of 2 ft. and a diameter of about 1 in. Where weeding and watering are not carried out the seedlings ordinarily reach a height of about 1-1½ ft. by the end of the second season. They continue growing till about November-December. The leaves turn yellow and fall about December-January, the new leaves appearing in March. The seedlings stand frost fairly well.

ARTIFICIAL REPRODUCTION. Plants raised by direct sowings, with weeding and watering, show better development than transplants. Owing to the hard covering of the seed germination is somewhat slow : if sown in April the seed does not as a rule germinate for three or four months, and sometimes not until the following year. Germination is said to be hastened by prolonged soaking in water or in moist cow-dung. If raised in seed-beds the seedlings may either be transplanted during the first rains without pruning, when they are a few inches high, or during the second rains ; in the latter case the long taproot should be pruned down to about 8 in. and the stem to about 2 in. from ground-level. In either case the transplanting causes a decided check to the growth, and a certain amount of mortality may be expected. Propagation by cuttings put in during the rains has been tried with success.

2. *Sapindus laurifolius*, Vahl. Syn. *S. emarginatus*, Vahl ; *S. trifolius*, Linn. Soapnut. Vern. *Ritha*, Mar. ; *Konkudu*, Tel. ; *Pungan kottei*, *nithavanji*, Tam. ; *Aratala*, Kan.

A large tree of the Indian Peninsula, chiefly in southern India, much cultivated for the sake of its fruits, the pulp of which is largely used as soap. It flowers from October to December, and the fruits, consisting of two to three indehiscent carpels 0.5-0.75 in. long, with a saponaceous flesh, ripen from February to April. In southern India it is fairly common in open forests at low elevations, and in some localities the fruits form an important article of



FIG. 96. *Sapindus detergentes*. Seedling $\times \frac{5}{8}$.
 a, fruit ; b, seed ; c-g, germination stages ; h, i, development of seedling during first season.

minor forest produce. Talbot says that it is distributed along the Western Ghats from the Konkan southwards in evergreen monsoon forests, while the variety *emarginatus* is usually confined to the dry deciduous forests of the Deccan and Carnatic.

ORDER XXI. ANACARDIACEAE

This order contains several important forest trees, some fruit trees which are largely cultivated, and certain species which yield varnishes of commercial value : some species have acrid juice which raises blisters.

Genera 1. RHUS, Linn. ; 2. PISTACIA, Linn. ; 3. SEMECARPUS, Linn. ; 4. ANACARDIUM, Rottb. ; 5. MANGIFERA, Linn. ; 6. BOUEA, Meissn. ; 7. BUCHANANIA, Roxb. ; 8. MELANORRHOEA, Wall. ; 9. ODINA, Roxb. ; 10. SPONDIAS, Linn.

1. RHUS, Linn.

This genus contains several species of shrubs or small trees, important mainly as undergrowth species.

Species 1. *R. succedanea*, Linn. ; 2. *R. Cotinus*, Linn. ; 3. *R. punjabensis*, J. L. Stewart ; 4. *R. parviflora*, Roxb.

1. *Rhus succedanea*, Linn., the Japanese lacquer tree, grows scattered throughout the greater part of the Himalayan region at 2,000–8,000 ft.

2. *Rhus Cotinus*, Linn., is found throughout the western Himalaya up to 6,000 ft., chiefly as an undergrowth species in *Pinus longifolia* forests.

3. *Rhus punjabensis*, J. L. Stewart, recognized by its large aromatic pinnate leaves, is found in the western Himalaya at 3,000–8,500 ft., usually in somewhat moist localities.

4. *Rhus parviflora*, Roxb., is a gregarious shrub or small tree which grows on bare hot slopes in the western Himalaya at 2,000–5,000 ft. and in the Pachmarhi hills and other hills of the Indian Peninsula. It is a useful plant for reclothing bare and unstable hill-sides, where, owing to its capacity for producing numerous root-suckers and its immunity from grazing, it often comes up in great profusion. Its trifoliate leaves give it somewhat the appearance of a *Desmodium* or of *Ougeinia dalbergioides*, with which it is sometimes associated : the leaves, however, are rather stiffer than those of *Desmodium* and smaller than those of *Ougeinia*. In the Himalaya the fruits ripen about June–July, when the trees are covered with the small orange-red drupes which dry before falling.

2. PISTACIA, Linn.

To this genus belongs the pistachio-nut tree, *P. vera*, Linn., a small tree of western Asia ; the pistachio-nuts are imported into India from Afghanistan.

Species 1. *P. integerrima*, J. L. Stewart ; 2. *P. mutica*, Fisch. and Mey.

1. *Pistacia integerrima*, J. L. Stewart. Vern. *Kakra*, *kakkar*, *kangar*, W. Him.

A moderate-sized deciduous tree with rough grey bark, viscous and aromatic when cut. Its pinnate leaves give it a superficial resemblance to the toon (*Cedrela Toona*), from which, however, it can be at once distinguished

by its aromatic inner bark, while its leaves are smaller and often imparipinnate, whereas the toon has paripinnate leaves. The tree is scattered throughout the western Himalaya up to 6,500 ft., often on dry hot slopes with shallow soil. In the Punjab it is common on steep rocky ground in *Pinus longifolia* forests, and is often associated with *Acacia modesta* and *Olea cuspidata*. It is cultivated successfully in gardens on the Punjab plains. The new leaves and flowers appear from March to May, and the fruit, an oblique drupe about 0.25 in. in diameter, ripens from June to October. The young leaves and inflorescences are red, and the trees are on this account very handsome in the spring. Mr. R. N. Parker says the seed is very frequently unfertile, probably owing to the flowers being dioecious and to there being no male tree near the plant from which the seed is collected. Natural regeneration appears chiefly under the protection of bushes, through which the saplings are capable of forcing their way; afterwards, however, the tree requires light and will not stand suppression. The leaves are browsed by cattle and goats. According to Gamble the rate of growth is 8 to 9 rings per inch of radius, representing a mean annual girth increment of about 0.7 to 0.8 in. A cross-section 3 ft. 4 in. in girth in the silvicultural museum at Dehra Dun showed 96 rings, representing a mean annual girth increment of 0.42 in. The wood, which is beautifully mottled, is used for furniture and ornamental carvings, and the leaves are lopped for buffalo and camel fodder.

2. *Pistacia mutica*, Fisch. and Mey. Vern. *Khanjak*, W. Him.

A small often gregarious tree, common on dry stony hills in Baluchistan at 4,000–7,500 ft. Coppice experiments in Baluchistan showed it to possess a coppicing power varying from 15 to 100 per cent. The following measurements of coppice-shoots have been recorded in different coupes: ¹

Age in years	.	1	3	4	5	6	8	9	10	11	12	13		
Height of coppice in feet.	{	Gwal												
		forest	.	—	3-5	4-6	4-7	5-9	10-14	10-14	12-16	12-16	12-16	13-16
		Hazar												
		Ganj												
		forest	.	2-4	2-4	3-5	3-6							

3. SEMECARPUS, Linn.

Semecarpus Anacardium, Linn. f. Marking-nut tree. Vern. *Bhilawa*, Hind.; *Bhela*, Beng.; *Biba*, Mar.; *Gero, ger*, Kan.; *Shenkotta*, Tam.

A moderate-sized deciduous tree with rough dark brown bark yielding an acrid juice. The tree is recognized by its large obovate leaves and typical fruits, consisting of an oblique drupe, black when ripe, situated on a fleshy orange-coloured receptacle; the black pericarp contains a corrosive juice used as marking-ink. The tree is found scattered in the sub-Himalayan tract, chiefly in sal forest, in Bengal, Assam, Chittagong, Chota Nagpur, and throughout the greater part of the Indian Peninsula. The old leaves are shed about February–March and the new leaves appear in May. The small greenish yellow flowers appear from May to September, and the fruits ripen from December to March. The tree seeds at a very early age; seed from coppice-shoots one year old was tested and found to be fertile, and it is quite usual

¹ Annual Forest Administration Report, Baluchistan, 1915–16.

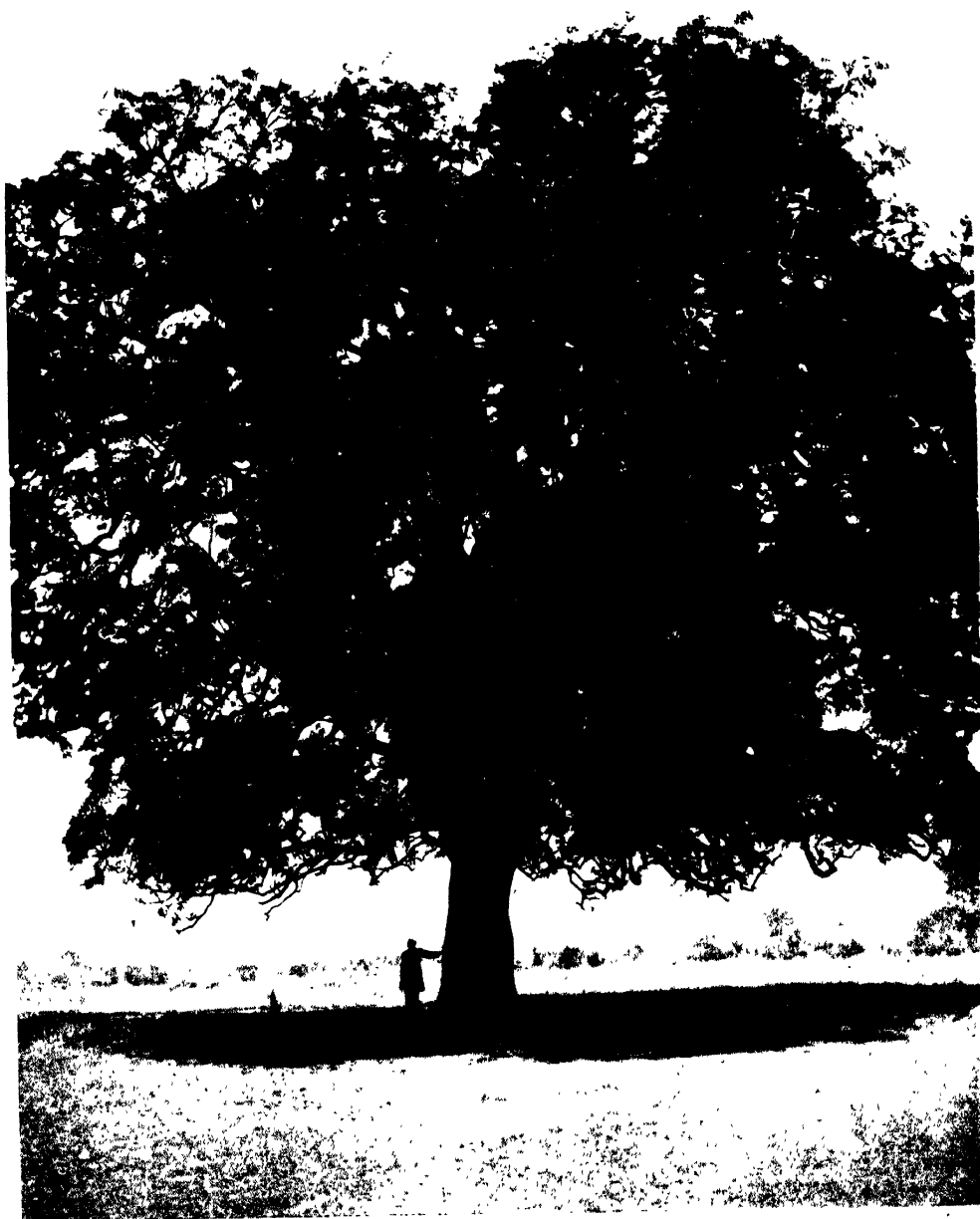


FIG. 97. *Mangifera indica*, Dehra Dun, United Provinces.



FIG. 98. *Odina Wodier*, Dehra Dun, United Provinces.

to see coppice-shoots two or three years old freely bearing fruits. The seedlings are rather sensitive to frost, but have good power of recovery. The tree is a moderate shade-bearer. It coppices well. Coppice measurements made in 1910 by Mr. C. M. McCrie in the Gorakhpur district, United Provinces, gave the following results for *Semecarpus Anacardium* as compared with sal :

Semecarpus Anacardium : coppice measurements, Gorakhpur.

Age. years.	Mean height.		Mean girth.	
	<i>Semecarpus</i> <i>Anacardium</i> . ft.	Sal. ft.	<i>Semecarpus</i> <i>Anacardium</i> . in.	Sal. in.
2	3.0	3.0	—	—
4	5.4	7.0	1.8	2.0
6	7.3	10.3	2.5	2.9
8	8.5	13.0	3.0	3.8
10	9.5	15.3	3.5	4.8
12	10.5	17.5	4.0	5.8

Measurements in 1911 in the Gonda district showed mean heights of 3 ft. and 5 ft. for coppice-shoots one and two years old respectively. Measurements in Bhandara, Central Provinces, in 1912–13 showed an average height of 4 ft. 9 in. for one-year-old coppice-shoots. As regards the rate of growth of trees, periodic measurements in six sample plots in the Siwalik, Lansdowne, Ramnagar, and Gonda forest divisions of the United Provinces showed mean annual girth increments for periods varying from 0.10 to 0.59 in.

4. ANACARDIUM, Rottb.

Anacardium occidentale, Linn. Cashew-nut tree. Vern. *Kaju*, Mar. ; *Godambe*, Kan. ; *Kolla-mavu*, Tam.

A native of South America, this tree has become established in many parts of the Indian Peninsula, particularly near the sea-coast, where it is often gregarious. It thrives best in sandy places and is important in the reclamation of sand-dunes. The flowers appear from December to April and the fruits ripen from March to June. It is used as an underwood in palmyra groves, and is best propagated by direct sowings. The wood is used for boat-building and other purposes, but the tree is best known as furnishing the cashew-nuts, which are roasted and eaten.

5. MANGIFERA, Linn.

Mangifera indica, Linn. Mango. Vern. *Am*, Hind. ; *Amba*, Mar. : *Maá*, Tam. ; *Mamidi*, Tel. ; *Mávu*, Kan. ; *Thayet*, Burm. (Fig. 97.)

A large evergreen tree with dark green coriaceous leaves and a dense rounded crown : bark thick, rough, dark grey. The mango tree is of great importance in India as a fruit tree and a shade tree for avenues and camping grounds. Its timber, which is not durable, is used for tea-boxes, packing-cases, planking, canoes, and other purposes. As a forest tree it is not of much importance, being nowhere found in great abundance.

DISTRIBUTION AND HABITAT. Probably indigenous in Burma, Assam, the Western Ghats and Satpuras, portions of the sub-Himalayan tract, Chota Nagpur, and perhaps in other localities. It is often found wild in the forest,

sometimes marking the sites of former villages and sometimes sprung from seeds discarded by man. In its natural state it affects ravines and other moist shady places. It is extensively cultivated throughout the greater part of India and Burma.

FLOWERING AND FRUITING. In southern India the flowers appear from January to March and the fruits ripen from April to July. In northern India flowering takes place from February to April, the fruit ripening in June–July. The small yellowish green flowers, in terminal panicles about 1 ft. long, are very strongly perfumed, but after maturing they lose their sweet smell and their odour becomes rather objectionable. Cultivated mangoes show great variety in size, shape, colour, and flavour: the wild fruits (Fig. 99, *a*) are about 2–4 in. long, without much flesh, but juicy and pleasantly flavoured. The seed, enclosed in a fibrous putamen, quickly loses its vitality, and requires to be sown soon after the fruit ripens. Abundant crops of fruit are not produced every year, and in some localities are produced not more than once in four or five years. Apparently climates which are too damp are unfavourable to the production of heavy crops at frequent intervals.

GERMINATION (Fig. 99, *b–d*). Hypogeous. The stout radicle emerges from the end of the seed, and the broad fleshy cotyledonary petioles elongate, enabling the young shoot to emerge. The cotyledons remain within the fibrous putamen on or below the ground.

THE SEEDLING (Fig. 99).

Roots: primary root moderately long, stout, terete, tapering, dark brown or black: lateral roots numerous, moderately thick, dark brown or black, distributed down main root. *Hypocotyl* distinct from root, 0.2–0.5 in. long, surrounded by the united decurrent bases of the cotyledonary petioles, the whole thick, fleshy, red, yellow or green, glabrous, subterranean. *Cotyledons* subterranean: petiole (free portion) 0.4–0.5 in. long, 0.25–0.4 in. broad, flattened, fleshy, curved to side of stem, united at the base to form a hypocotyledonary tube surrounding the stem: lamina 1.3–2.5 in. by 0.9–1.3 in., thick, fleshy, obliquely ovate or reniform, outer surface convex, smooth, inner flattened with a longitudinal concave groove, white, pale yellow, pink or green. *Stem* erect, terete, dark red, green or greenish red, glabrous; first internode, above the cotyledons, 8–12 in., subsequent internodes 0.1–1.2 in. long. *Leaves* simple, exstipulate, first one, two, or three pairs opposite or sub-opposite, or all leaves alternate. Petiole 0.3–0.6 in. long, grooved above, glabrous. Lamina 3.5–6.5 in. by 1.1–2.2 in., oblong lanceolate, acuminate, entire, glabrous, delicate and usually coppery red in young stages, coriaceous, dark green and shining when mature, lateral veins distinct, arcuate, numerous.

The early growth of the seedling is rapid, a bare stem 8–12 in. long being formed a short time after germination; at the top of this stem the foliage leaves appear at fairly close intervals. By the end of the first season a height of 1–1½ ft. is ordinarily attained if watering and weeding are carried out, while under similar conditions a height of 2½ to 5 ft. may be attained by the end of the second season and a height of 5 to 9 ft. by the end of the third season. In northern India the season's growth ceases about November and new growth commences about March. The seedlings stand a fair amount of shade and resist slight frosts, but require protection where frost is at all severe.

SILVICULTURAL CHARACTERS. The mango tree is a shade-bearer. It prefers a deep well-drained loamy soil and a moist warm climate: if cultivated



FIG. 99. *Mangifera indica*. Seedling.

a, fruit $\times \frac{1}{2}$; *b-d*, germination stages $\times \frac{2}{3}$; *e, f*, development of seedling during first season $\times \frac{2}{3}$.

in a dry locality it requires watering for several years, and even with special tending it does not attain the dimensions which it reaches in a moister climate. It withstands ordinary frosts, but in the abnormal frost of 1905 in northern India the mango trees suffered very severely. In the severe drought of 1907 and 1908 in Oudh the mango topes in many places were badly damaged,

some having been entirely destroyed : in the abnormal drought of 1899–1900 in the Central Provinces the trees were likewise killed off in considerable numbers. Gamble says that in unsuitable places young mango trees suffer from the sun, and that in southern India, as pointed out by Mr. Higgins in reference to Cuddapah topes, the bark on the western side often gets cracked by hot winds and dries up, when the white ants come and soon make a serious and unsightly wound.

NATURAL REPRODUCTION. The seeds germinate readily on the surface of the ground at the commencement of the rainy season, and the seedlings have little difficulty in establishing themselves, particularly if shaded to some extent from the sun ; the ground around mango trees may sometimes be found carpeted with seedlings up to 1 ft. high at the end of the first season. Where the young plants receive protection, as in bushes, hedges, &c., mango saplings often make their way through the cover in quantity, but if exposed to the sun they die off in large numbers during the dry season.

ARTIFICIAL REPRODUCTION. In India the best varieties of cultivated mango are propagated by grafting. In Burma, however, good varieties are frequently propagated successfully from seed. For growing in avenues or topes the trees are always raised from seed, either by sowing *in situ* or by transplanting nursery-raised plants ; the former method is to be recommended in preference to the latter. The pulp should be removed from the stone, and the latter should be sown as soon after ripening as possible in rich well-loosened soil. Nursery-raised plants can be transplanted without much difficulty during the first rains provided this is done fairly early, before the taproot has developed to any great extent ; it is preferable, however, to raise the seedlings in baskets. During the first two or three years it is advisable to protect the young plants from frost and sun and also to water them in dry weather.

6. BOUEA, Meissner.

Bouea burmanica, Griff. Syn. *B. oppositifolia*, Meissn. Vern. *Miriam*, Beng. ; *Mayan*, Burm.

A moderate-sized handsome evergreen tree with a dense crown of shiny lanceolate leaves, indigenous in the Andamans and Tenasserim and probably in the Sundarbans ; much cultivated as a fruit tree in the moister parts of Burma. The fruit, which ripens about April–May, is a yellow drupe resembling a miniature mango but somewhat inferior to it in flavour. The seeds do not retain their vitality long, and should be sown quite fresh. The tree is best propagated by sowing *in situ* or by raising plants in baskets : it requires a moist climate and situation. The growth is slow.

7. BUCHANANIA, Roxb.

Buchanania latifolia, Roxb. Syn. *B. Lanza*n, Spreng. Vern. *Chiroli*, pial, achar, Hind. ; *Char*, Hind., Mar. ; *Morli*, sara, Tel. ; *Nurkal*, Kan. ; *Morala*, Tam. ; *Lônbo*, Burm.

A moderate-sized tree, almost evergreen, with a straight trunk ; bark dark grey or black, 0.5–0.8 in. thick, regularly divided into small rectangular plates somewhat resembling crocodile hide, reddish inside. The wood is of

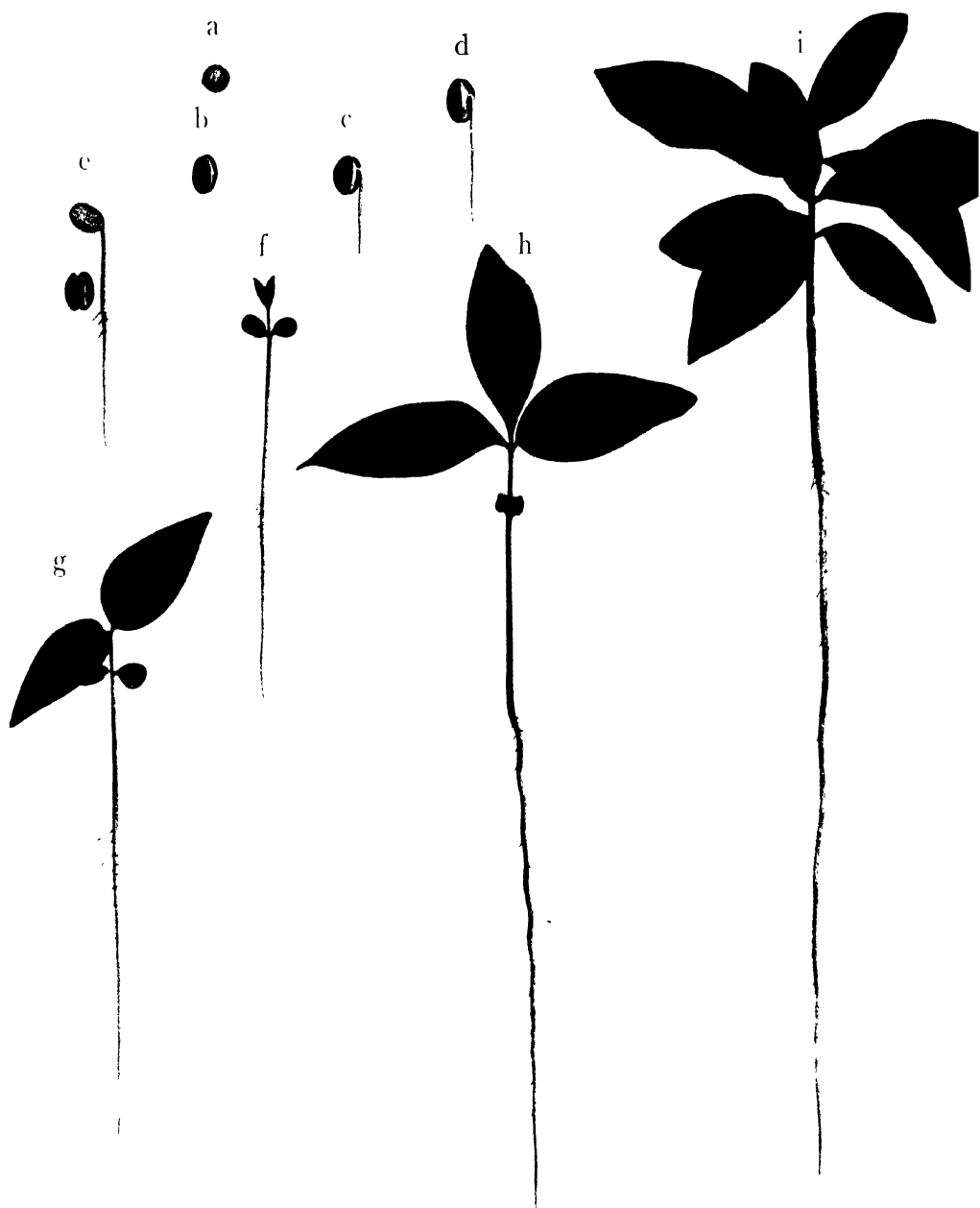


FIG. 100. *Buchanania latifolia* SEEDLING $\times \frac{1}{2}$

a—Seed b-e Germination stages f-i Development of seedling during first season

poor quality, but the tree is of some economic importance for the gum and edible fruits which it yields. Its silvicultural importance lies in its great abundance in certain common types of forest and its utility for clothing dry hills.

DISTRIBUTION AND HABITAT. In deciduous forests throughout the greater part of India and Burma, except in the arid regions of north-western India. In the sub-Himalayan tract it occurs on the dry outer Himalayan and Siwalik slopes up to 3,000 ft. elevation, from the Sutlej to Nepal, very commonly mixed with the small-sized sal of these hills or with *Anogeissus latifolia* and extending at times into the lower limits of *Pinus longifolia*. It is also common in the drier types of sal forest in the sub-Himalayan tract outside the hills and in the Indian Peninsula, where it is also abundant in mixed deciduous forests, particularly of the drier types. It is often found in abundance on clayey soil. In Burma it is characteristic of dry open forests and is particularly common in *indaing* forest on laterite soil, associated with *Dipterocarpus tuberculatus*, *Pentacme suavis*, *Shorea obtusa*, and *Melanorrhoea usitata*: it extends into the deciduous forests of the dry zone of Upper Burma. In Travancore it is very common in all deciduous forests up to 4,000 ft. (Bourdillon). In its natural habitat the absolute maximum shade temperature varies from 105° to 115° F., the absolute minimum from 30° to 55° F., and the normal rainfall from 30 to 85 in.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The tree is leafless or nearly so for a very short time during the hot season. The pyramidal panicles of small greenish white flowers appear from January to March and the fruits ripen from April to June. The fruit is an ovoid drupe about 0.5 in. long, black when ripe, with a hard two-valved stone 0.35–0.4 in. in diameter (Fig. 100, *a*) enclosing an oily seed; about 100–120 stones weigh 1 oz. Tests carried out at Dehra Dun with seed stored in an air-tight tin for one year showed a fertility of 50 per cent. It was found, however, that seed exposed to the sun soon lost its vitality. Fresh seed was found to have a fertility of about 70 per cent.

GERMINATION (Fig. 100, *b–e*). Epigeous. It commences with the splitting of the fruit-stone into two equal valves, the radicle pushing its way through the opening; the hypocotyl arches slightly, withdrawing the fleshy cotyledons from the stone and raising them above ground, the valves of the stone remaining on or under the ground.

THE SEEDLING (Fig. 100).

Roots: primary root long, thick, terete, tapering, somewhat delicate in texture for a time: lateral roots moderate in number, fibrous, distributed down main root. **Hypocotyl** distinct from the root, 1.5–2 in. long, terete, tapering upwards, green, pubescent. **Cotyledons:** petiole 0.1 in. long or less, flattened above, pubescent: lamina 0.3–0.35 in. by 0.2–0.25 in., thick, fleshy, elliptical, apex rounded, base contracted, outer surface rounded, inner flattened, green, glabrous. **Stem** erect, terete, pubescent; internodes 0.2–0.7 in. long. **Leaves** simple, exstipulate, first pair or sometimes two pairs opposite, subsequent leaves alternate. Petiole 0.1–0.15 in. long, flattened above, pubescent. Lamina 1.5–2.8 in. long, ovate or elliptical, obtuse or acute, base acute or rounded, entire, dark green above, paler beneath, glabrous above, pubescent on principal veins beneath and on margins, lateral veins 8–16 pairs, slightly impressed on upper surface.

The development of the seedling is slow, even under favourable conditions.

By the end of the first season, even if regular weeding is carried out, the plants do not ordinarily attain a height of more than 3 in. Watering appears to have little effect on the growth, and during the first season the seedlings develop fairly well in a moderate growth of grass and weeds : subsequently, however, weeds tend to hamper their growth or to kill them out. If regular weeding is carried out maximum heights of 18 in. and 4½ ft. may be attained by the end of the second and third seasons respectively, but on unweeded ground the growth is considerably slower. The seedlings are very sensitive to frost, particularly on grass-covered ground : they are also sensitive to drought and are subject to insect attacks. They require well-drained ground, as the roots tend to rot off in water-logged soil.

SILVICULTURAL CHARACTERS. The tree is a moderate light-demander. It is very sensitive to frost, and somewhat sensitive to drought, having suffered considerably in the abnormal drought of 1899 and 1900 in the Central Provinces. It is not readily browsed. Silviculturally it is a useful tree for clothing dry hill-sides within its natural region. It avoids water-logged ground. It produces root-suckers and coppice-shoots, though its coppicing power varies. Mr. A. E. Osmaston¹ records that, in experiments in the Gorakhpur forests in 1909-10, of 26 trees coppiced only 4 per cent. of the stools produced shoots. These experiments were, however, conducted after abnormal seasons of drought which may have affected the vigour of the stools. Measurements in the same forests by Mr. C. M. McCrie in 1910 showed an average varying from 1 to 3.58 shoots per stool in coupes 1 to 16 years old. In the Gonda district, United Provinces, in 1911 I found the average to be 2.2 and 1.5 shoots per stool in coupes 1 and 2 years old respectively.

NATURAL REPRODUCTION. The fruits fall immediately before or at the commencement of the rainy season. If they are quickly covered with earth or débris by the rain, or are protected by grass or other low cover, germination soon commences and the seedlings have a chance of establishing themselves, developing slowly. Seeds lying on the surface of the ground exposed to the sun either fail to germinate and soon lose their vitality or, if they germinate, the radicles tend to dry up ; much mortality is caused in this way. Another fruitful cause of mortality is the destruction of the radicle by insects. Under favourable conditions natural reproduction appears in quantity, almost gregariously in places ; part of the natural reproduction found in the forest consists of root-suckers, particularly on hilly ground and where the roots are liable to be exposed.

ARTIFICIAL REPRODUCTION. Care should be taken not to collect seeds which have lain on the ground exposed to the sun for any time, as these have a low percentage of fertility. Experiments at Dehra Dun have shown that direct sowing is more successful than transplanting from nursery beds, whether the latter is carried out during the first or the second rains, and whether the taproot and stem are pruned down or not. This species has been raised with others in line sowings in conjunction with the cultivation of field crops in the Amraoti district, Berar.

RATE OF GROWTH. Available statistics show that the rate of growth of seedling trees is slow. Periodical measurements of ninety-seven trees in sample

¹ Ind. Forester, xxxvii (1911), p. 429.

plots in the submontane tract of the Saharanpur Siwaliks gave the following rate of growth :

Buchanania latifolia : rate of growth in sample plots, Siwaliks.

Age. years.	Girth. ft. in.	Age. years.	Girth. ft. in.
40	0 5	140	2 0
60	0 8	160	2 6
80	1 0	180	3 0
100	1 4	200	3 6
120	1 8	220	4 0

Measurements in six sample plots in the Lansdowne and Ramnagar forest divisions of the United Provinces showed mean annual girth increments varying from 0·07 to 0·56 in. In the Bhira range, Kheri, United Provinces, sample plot measurements showed periodical mean annual increments of 0·56 in. for two trees 2–3 ft. in girth, and 0·12 in. for one tree 3–4 ft. in girth. A cross-section 3 ft. 2 in. in girth in the silvicultural museum at Dehra Dun showed 43 rings, representing a mean annual girth increment of 0·88 in.

As regards coppice, measurements made in 1910 by Mr. C. M. McCrie in Gorakhpur, United Provinces, gave the following results for *Buchanania latifolia* as compared with sal :

Buchanania latifolia : coppice measurements, Gorakhpur.

Age. years.	Mean height.		Mean girth.	
	<i>Buchanania latifolia</i> . ft.	Sal. ft.	<i>Buchanania latifolia</i> . in.	Sal. in.
2	4·7	3·0	—	—
4	8·0	7·0	2·8	2·0
6	10·2	10·3	3·7	2·9
8	11·8	13·0	4·6	3·8
10	13·1	15·3	5·1	4·8
12	14·2	17·5	5·5	5·8
14	15·0	19·2	5·7	6·7
16	15·8	20·9	5·9	7·5

Coppice measurements in Gonda, United Provinces, in 1911 showed a mean height of 4·2 and 5·5 ft. in coupes one and two years old respectively.

8. MELANORRHOEA, Wall.

Melanorrhoea usitata, Wall. Varnish tree of Burma. Vern. *Thitsi*, Burm.

A large deciduous tree with a straight clean cylindrical bole and a spreading crown of dark green leaves. Bark thin, dark grey, exfoliating in small angular flakes. Wood dark red, very hard, used for tool-handles, ploughs, building, &c. The chief importance of the tree lies in the varnish obtained from incisions made in the bark and used in Burmese lacquer work. In most parts of Burma the tree attains a height of 50–60 ft. and a girth up to 9 ft. A tree 14 ft. 6 in. in girth has been measured in the Katha district of Upper Burma, but this is exceptional.

DISTRIBUTION AND HABITAT. This is one of the most characteristic trees of the *indaing* (dry dipterocarp) forests of Burma on laterite soil, where it is associated with *Dipterocarpus tuberculatus*, *Pentacme suavis*, *Shorea obtusa*,

Buchanania latifolia, and certain other species. It is less common in other types of dry forest, where it prefers gravelly or sandy soil. It ascends to 3,500 ft. and occurs between 15° and 25° N. lat., the most extensive tracts in which it is found being situated in the Southern Shan States, and in the Mu, Katha, Myittha, Upper Chindwin, Ruby Mines, Meiktila, N. Toungoo, and Thayetmyo forest divisions. It has not been reported from Arakan, but extends into Manipur. It is very common in parts of the Southern Shan States, often forming half the growing stock. In its natural habitat the absolute maximum shade temperature varies from 100° to 110° F., the absolute minimum from 40° to 50° F., and the normal rainfall from 35 to 100 in. or more.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The leaves are shed about January–February, and the new leaves appear in March–April. The panicles of small white flowers appear in January–February, when the tree is leafless or nearly so; when covered with white blossom it is a conspicuous sight. The fruits ripen from March to June. The fruit is an irregularly globose drupe (Fig. 101, *a*), the longest diameter 0.5–0.9 in., on a thick stalk 0.3–0.4 in. long, subtended by the five enlarged stellately-spreading stiff membranous petals 2–4 in. long, which are bright red at the time of ripening, turning brown afterwards. The fruits fall parachute-like, revolving rapidly, and may be carried to some little distance from the tree by the strong dry breezes which are prevalent in many localities at the time they ripen. The seed does not retain its vitality long, and germinates soon after falling. Good seed-years are somewhat irregular.

GERMINATION (Fig. 101, *b*, *c*). Hypogeous. The radicle issues, while simultaneously short cotyledonary petioles are developed, between which the plumule emerges. Several roots are developed at an early stage from the base of the young stem.

THE SEEDLING (Fig. 101).

Roots: primary root, usually more than one, moderately long, thick, woody; lateral roots numerous, fibrous, mainly in upper parts of main roots, developing early. *Hypocotyl* absent. *Cotyledons* subterranean: petiole 0.1–0.15 in. long, flattened on inner side: lamina 0.8–0.9 in. by 0.5 in., thick, fleshy, closely cohering, reniform, outer surface rounded, rugulose, inner surface flattened in contact, smooth. *Stem* erect, terete or slightly compressed, green, young parts minutely tomentose, older parts glabrous; internodes 0.4–2 in. long. *Leaves* alternate, exstipulate. Petiole 0.2–0.35 in. long, thick, flattened or channelled above, pubescent or glabrescent. Lamina 1.7–4.6 in. by 1.1–2.5 in., elliptical or obovate, acuminate, base decurrent, entire, glabrous or young leaves sometimes sparsely pubescent beneath, lateral veins 12–16 pairs, conspicuous, running to near the margin. First few leaves usually rudimentary and very small.

The seedling develops somewhat slowly, a height of about 4 or 5 in. being ordinarily attained by the end of the first season; the taproot may attain a length of about 1 ft. or more in that time. The seedlings will not stand cold, and are killed at once by frost.

SILVICULTURAL CHARACTERS. The silvicultural characters of the tree have not been studied in any detail. It is known to be immune from damage by grazing owing to the acrid juice in its leaves. Although a light-demander the tree appears to be able to bear slight shade and to benefit by it in youth.



FIG. 101. *Melanorrhæa usitata*—SEEDLING $\times \frac{3}{8}$

a—Fruit (without wings) b, c—Germination stages d, e—Development of seedling during first season
 f—Seedling after commencement of second season

ARTIFICIAL REPRODUCTION. Experiments have shown that transplanting from the nursery is attended with some risk, and that direct sowing, or transplanting of basket plants, gives better results. The fruits should be collected and sown as soon after ripening as possible, since germination commences not long after they fall.

9. ODINA, Roxb.

Odina Wodier, Roxb. Vern. *Kaimal, jhingan, jigna, mohin*, Hind. ; *Jial*, Beng. ; *Gugul*, Kan. ; *Moi, shembat*, Mar. ; *Uthi, odi*, Tam. ; *Gumpun*, Tel. ; *Nabè*, Burm. (Fig. 98.)

A moderate-sized to large deciduous tree with a spreading crown, stout branchlets, and compound imparipinnate leaves 12–18 in. long. Bark 0.5–0.7 in. thick, grey, smooth in young trees, afterwards exfoliating in thin irregular rounded plates, inside crimson marked with pale pink or white. Heartwood comparatively small, light pink when freshly cut, darkening on exposure, of good quality, used for planking, agricultural and domestic implements, and a variety of other purposes. The bark yields a useful gum which is largely exploited by tapping.

DISTRIBUTION AND HABITAT. A common tree in mixed deciduous forests throughout the greater part of India and Burma and in the Andamans. It occurs throughout the sub-Himalayan tract in sal forests and mixed deciduous forests of the plains and outer hills, ascending the Himalayan valleys and slopes to 4,000 ft. It is common, especially in dry forests, in Bengal, Assam, Chota Nagpur, and throughout the Indian Peninsula. In Burma it is plentiful in both the upper and the lower mixed forests. In its natural habitat the absolute maximum shade temperature varies from 100° to 118° F., the absolute minimum from 30° to 60° F., and the normal rainfall from 30 to 150 in. or more.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The leaves commence falling in November, and from December–January to May–June the tree is leafless. The flower-buds appear about February in stiff terminal racemes at the ends of the leafless branches, and in March–April the trees have a striking appearance when covered with masses of feathery whitish blossoms. The fruits begin to form rapidly, becoming nearly full-sized while the tree is still leafless, and ripening from May to July : the trees at this time are easily recognized from the clusters of small drupes. When ripe the drupe is about 0.5 in. long, oblong, sub-reniform, compressed, red, with a thin fleshy epicarp and a large hard stone. The fruits are eaten by birds and the stones are scattered by their agency. The seeds quickly lose their vitality.

SILVICULTURAL CHARACTERS. The tree is a decided light-demander. It is tender to frost and suffered much in northern India in the severe frost of 1905. In the abnormal drought of 1907 and 1908 in Oudh it proved to be decidedly hardy, and it was only slightly affected in the excessive drought of 1899 and 1900 in the Deccan. It resists fire well. The leaves and young shoots are readily browsed by cattle and goats. It pollards fairly well and produces root-suckers. Its coppicing power varies. Mr. A. E. Osmaston¹ notes that, in experiments in the Gorakhpur forests in 1909–10, of 18 trees felled none

¹ Ind. Forester, xxxvii (1911), p. 429.

produced coppice-shoots ; these experiments, however, were carried out after abnormal years of drought, which may have affected the vitality of the stools. Measurements by Mr. C. M. McCrie in the same forests in 1910 showed an average of 3, 2, 1, and 1 shoots per stool in the case of coppice 5, 7, 13, and 15 years old respectively, while measurements by me in the Tikri forest, Gonda, United Provinces, in 1911, showed an average of two shoots per stool in one-year-old coppice.

ARTIFICIAL REPRODUCTION. The tree grows well from seed or from cuttings. The seed should be sown fresh, as it does not retain its vitality long.

RATE OF GROWTH. Statistics of rate of growth are scanty. Measurements of one tree extending over nineteen years in the Ramnagar division, United Provinces, showed a mean annual girth increment for the period of 0.32 in. Two cross-sections in the silvicultural museum at Dehra Dun showed the following measurements :

1. Age 73 years ; girth 3 ft. 9 in. ; mean annual girth increment 0.62 in.
2. Age 49 years ; girth 3 ft. 10 in. : mean annual girth increment 0.94 in.

The rate of growth of coppice is fast. Coppice measurements made in 1910 by Mr. C. M. McCrie in Gorakhpur gave the following average results for *Odina Wodier* and sal respectively :

Odina Wodier : coppice measurements, Gorakhpur, United Provinces.

Age. years.	Mean height.		Mean girth.	
	<i>Odina Wodier</i> .	Sal.	<i>Odina Wodier</i> .	Sal.
	ft.	ft.	in.	in.
2	5.8	3.0	2.3	—
4	10.9	7.0	4.1	2.0
6	14.2	10.3	5.8	2.9
8	16.7	13.0	7.3	3.8
10	19.0	15.3	8.6	4.8
12	21.1	17.5	9.8	5.8
14	22.9	19.2	10.8	6.7
16	24.3	20.9	11.5	7.5

My measurements in 1911 in one-year-old coppice coupes in the Tikri forest, Gonda, showed an average height of 5 ft. for *Odina* as against 4 ft. 8 in. for sal.

10. SPONDIAS, Linn.

Spondias mangifera, Willd. Hog plum. Vern. *Amra*, *ambara*, Hind. : *Ambada*, Mar. : *Amate*, Kan. : *Ambalam*, Tam. : *Gwè*, Burm.

A moderate-sized to large deciduous tree with compound imparipinnate fragrant leaves 12–18 in. long. Bark thick, smooth, grey, aromatic, inside pink streaked with lighter pink. Wood soft and of poor quality : the tree yields a tasteless gum and the fruits are pickled. A characteristic Indian forest tree.

DISTRIBUTION AND HABITAT. Throughout the greater part of India and Burma in deciduous, often dry forests. Throughout the sub-Himalayan tract, in Bengal, Assam, Chota Nagpur, the Indian Peninsula generally, Burma, and the Andamans. Although widely distributed it is nowhere abundant or gregarious. In its natural habitat the absolute maximum shade temperature

varies from 100° to 118° F., the absolute minimum from 30° to 60° F., and the normal rainfall from 30 to 150 in. or more.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The tree is leafless longer than almost any other forest tree of India. The leaves fall in November–December, sometimes earlier, and the tree remains leafless until April–May or even later. The inflorescences of whitish flowers cover the leafless trees about March–April, and at that time the trees are a conspicuous sight. The fruits form during the rains and commence to ripen in December, continuing to ripen and fall until February or March. The trees at this time are easily recognized by the pendulous clusters of drupes. The drupes are 1.5–2 in. long, ellipsoidal, yellow when ripe, smooth, fleshy, with a hard somewhat fibrous stone furrowed and pitted on the surface; the stone (Fig. 102, *a*) is 2- to 5-celled, sometimes 6-celled, with 1–3 fertile seeds. The fruits are greedily eaten by deer, pigs, monkeys, squirrels, and other animals, and the large bare stones with the flesh removed may be found scattered about the forest from the time the fruit ripens onwards. Small heaps of these stones are continually met with in places where deer have lain ruminating and bringing them up. The seed of stones collected from these heaps has been found to germinate well. About 70–130 stones weigh 1 lb. Tests carried out at Dehra Dun showed that a proportion of the seeds retained their vitality for one year, namely 60 seeds per 100 stones as against 130 seeds in the case of fresh stones; another sample kept for a similar period failed to germinate.

GERMINATION (Fig. 102, *b–d*). Epigeous. The radicle and plumule emerge almost simultaneously through a hole near one end of the fruit-stone, the testa remaining within the stone. The hypocotyl arches during germination, soon straightening: there is a distinct kink or elbow at its base owing to the efforts of the seedling to emerge from the stone. From one to three seedlings may emerge from the same stone, so that the seedlings are sometimes found in groups of two or three.

THE SEEDLING (Fig. 102).

Roots: primary root moderately long, at first thin, soon becoming thick and somewhat fleshy, terete, tapering, whitish, tomentose: lateral roots numerous, long, fibrous, tomentose, distributed down main root. **Hypocotyl** distinct from root, 1.5–3 in. long, terete, tapering slightly upwards, with a distinct bend at the base, fleshy, green, glabrous, arched during germination. **Cotyledons** sessile, 1.2–1.5 in. by 0.3 in., somewhat fleshy, linear lanceolate, acute, entire, green, glabrous, obscurely parallel veined on lower surface. **Stem** erect, terete or slightly grooved, glabrous; internodes 0.4–1.2 in. long. **Leaves** compound, exstipulate, first pair opposite or sub-opposite, subsequent leaves alternate. First pair 3-foliate, common petiole 0.4–1.2 in. long. Subsequent leaves imparipinnate, usually 5- or 7-foliate in first season; rachis 0.8–4 in. in first season, often reddish; leaflets shortly petiolate, 1–3.5 in. by 0.5–1.3 in., elliptical oblong, acuminate, serrate or entire, glabrous.

During the first year or two the seedlings show moderately fast development under natural conditions, that is, where no weeding and watering is done; subsequently they develop more rapidly. They are capable of establishing themselves in grass and moderate weed-growth, but weeding greatly stimulates their growth. The maximum height of seedlings raised at Dehra Dun, and not watered, was as follows:

(1) End of first season 7 in., both weeded and unweeded; (2) end of

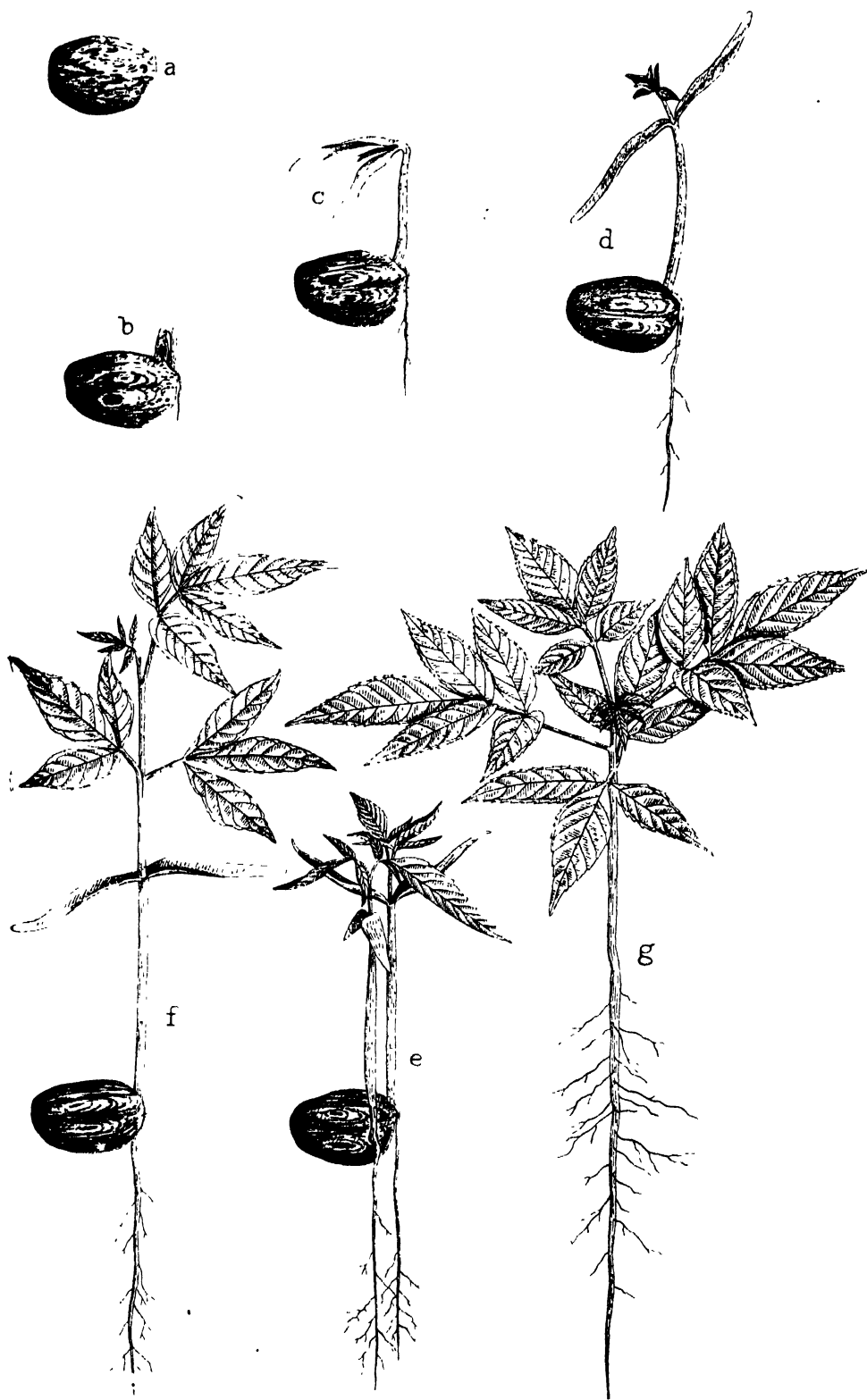


FIG. 102. *Spondias mangifera*. Seedling $\times \frac{1}{2}$.
 a, stone of drupe ; b-d, germination stages ; e-g, development of seedling to end of first season.

second season 21 in. unweeded, 34 in. weeded ; (3) end of third season 5 ft. 10 in. unweeded, 9 ft. 2 in. weeded ; (4) end of fourth season 6 ft. unweeded, 12 ft. 9 in. (girth 7 in.) weeded. Where two or three seedlings emerge from one fruit one eventually takes the lead, suppressing the others. In northern India the season's growth ceases about October–November, and new growth commences in March–April ; the seedlings are leafless from December to March–April. The seedlings are somewhat frost-tender, but have good power of recovery from the base : they are also sensitive to drought in the first year or two. Rats are occasionally destructive to them, gnawing through the taproot and killing them.

SILVICULTURAL CHARACTERS. The tree is a decided light-demander. It is sensitive to frost, and suffered much in northern India in the abnormal frost of 1905. It coppices, but is not known to produce root-suckers.

NATURAL REPRODUCTION. The fruit-stones, from which the fleshy covering has usually been stripped by animals, lie on the ground from the time the fruits fall in the cold season until the rains, when germination takes place. If the stones are lying on the surface of the ground at the time of germination the radicle is very apt to dry up or to become eaten by birds or insects before it reaches the soil. Many stones, however, become covered with earth and debris during the months in which they lie on the ground, and particularly during the early showers preceding the monsoon rains : this promotes successful germination, which is still further ensured by the fact that many fruits do not germinate until the second rains, and thus have every opportunity of becoming covered with earth during the long period in which they lie on the ground. For the establishment of natural reproduction, abundance of light is necessary.

ARTIFICIAL REPRODUCTION. The tree can be propagated from cuttings or from seed. In the latter case direct sowings give better results than transplanting, provided the fruit-stones are covered with earth. Nursery-raised seedlings should be transplanted when about 3 in. high during the first rains, but considerable care is necessary to retain earth round the roots and to avoid exposing them. More success is attained by transplanting seedlings raised in baskets.

RATE OF GROWTH. The rate of growth is known to be fairly rapid, though detailed measurements are not available. A cross-section 2 ft. 6½ in. in girth in the silvicultural museum at Dehra Dun showed 22 rings, representing a mean annual girth increment of 1.4 in.

ORDER XXII. MORINGACEAE

MORINGA, Lam.

Moringa pterygosperma, Gaertn. Syn. *M. oleifera*, Lam. Horse-radish tree. Vern. *Sanjna*, *sohanjna*, Hind. ; *Shevgi*, Mar. ; *Nuggi*, Kan. ; *Moringa*, Tam. ; *Danthahun*, Burm.

A small to moderate-sized tree with thick soft grey corky deeply fissured bark and elegant feathery foliage of large tripinnate leaves. The wood is soft and useless, but the fruit is used as a vegetable, the branches are much lopped for fodder, especially for camels, and the inner bark, and more particularly

the roots, are used as a substitute for horse-radish, which they resemble in flavour. The seeds yield an oil of fine quality similar to the *ben* oil of watch-makers, which is the produce of *M. aptera*, Gaertn., an African tree. The cultivation of *M. pterygosperma* for the sake of this oil has been recommended. The tree is indigenous in the sub-Himalayan tract from the Chenab to the Sarda, and in Oudh, growing plentifully on recent alluvial land in or near the sandy or shingly beds of rivers and streams. In its natural habitat the absolute maximum shade temperature varies from 110° to 118° F., the absolute minimum from 30° to 37° F., and the normal rainfall from 30 to 85 in. It is cultivated in many parts of India. The leaves turn yellow and fall in December–January, the leaflets falling separately, and the new foliage appears about February–March. The fragrant handsome white flowers, in numerous panicles near the ends of the branches, appear from January to March, and the fruits ripen from April to June. The fruit is a pendulous ribbed pod-like capsule, 9–20 in. long, with numerous three-cornered seeds winged at the angles. The trees can be raised either from seed or from large cuttings, the latter striking well if watered sufficiently. It coppices and pollards vigorously.

ORDER XXIII. LEGUMINOSAE

Includes sub-orders I. PAPILIONACEAE, II. CAESALPINIEAE, III. MIMOSEAE.

This order is, numerically speaking, by far the most important one in Indian silviculture, containing as it does a much larger number of important trees than any other order. In addition to trees, it includes numerous shrubs of the undergrowth or of open places, some useful for clothing barren ground, such as *Cassia auriculata*, *Acacia* spp., *Dichrostachys cinerea*, &c., or bare hill-sides, for example *Desmodium*, *Indigofera*, &c.; others of a scrambling or scandent nature, impeding forest growth. Many of the large climbers, which require to be cut periodically in the interests of tree growth, belong to this order: some of the best known of these are *Millettia auriculata*, *M. racemosa*, and other species of *Millettia*, *Spatholobus Roxburghii*, *Butea superba*, *Mucuna macrocarpa*, *Derris scandens*, *Bauhinia Vahlia* and several other species of *Bauhinia*, *Entada scandens*, *Acacia pennata*, and other scandent acacias.

Many species are cultivated for the sake of their ornamental flowers, for example *Amherstia nobilis*, one of the most beautiful flowering trees in the world, *Poinciana regia*, *P. elata*, *Saraca indica*, *Cassia Fistula*, *C. renigera*, *C. nodosa*, and many others. Many yield economic products of value, such as tans furnished by *Caesalpinia digyna* and *C. Coriaria* (pods), *Cassia auriculata* (bark), *Acacia arabica* (bark and pods), *A. leucophloea* (bark), and *A. Catechu* (cutch extract from the heartwood), gums yielded by *Acacia Senegal*, *A. arabica*, *A. modesta*, *Bauhinia retusa*, *Pterocarpus Marsupium* (gum-kino), and *Butea frondosa*, bast-fibres, drugs, and other products.

Among such a large number of genera and species the silvicultural characters vary considerably, though some of these characters are common to a good many. Perhaps one of the most marked characteristics is the effect of soil-aeration on the development of young plants. In the descriptions of the seedlings of the various species many examples will be found of the marked growth obtained on ground kept well weeded and loosened, as compared with

the growth on ground not weeded and loosened: this is true of plants in general, but it is perhaps nowhere so well marked as in the case of the Leguminosae, a fact which may possibly be due, in part at least, to the effect of aeration on the nitrogen-fixing nodules found on the roots of many of the species.

The pods and their dehiscence, and the spread and germination of the seed, are of considerable interest. Among pods which are indehiscent even during germination are those of *Dalbergia* spp., in which the young plant breaks through the pod valves. The pods of *Cassia Fistula*, as far as can be ascertained, require the aid of animals to liberate the seeds. In the case of *Acacia arabica* pods, although the seed is usually scattered by animal agency the pods may otherwise lie on the ground until the valves rot, the seed escaping in this way. In *Butea frondosa*, *Pongamia glabra*, *Ougeinia dalbergioides*, *Pterocarpus* spp., and *Hardwickia binata* dehiscence, which may be only partial, takes place during germination; in the first two species germination is hypogeous, the cotyledons remaining within the pod or sometimes escaping from it, while in the remainder germination is epigeous and the pod valves are always thrown off before germination is completed. Of pods which dehisce tardily, and as a rule after falling, may be mentioned those of *Acacia Farnesiana* and of several species of *Albizzia*; the pods of the latter are flat and thin, and can be blown some distance by the wind, the seed being thus disseminated. Pods which dehisce on the tree before or about the time of falling may be of two types: (1) those in which the seeds cling by means of a tenacious funicle to the pod valves, which in many cases are light and are easily carried by wind, the seeds being thus scattered to some distance from the tree, for example *Robinia Pseudacacia*, *Acacia Catechu*, and *A. Melanoxydon*; (2) those from which the seed falls out during or not long after dehiscence, and is in some cases ejected and scattered by the sudden opening of a pod with woody elastic valves, for example *Xylia* and some species of *Bauhinia*.

Among light or flat pods, in some cases winged, which are adapted for disseminating the seed by wind, may be mentioned those of *Pterocarpus* spp. (winged), *Hardwickia binata* (winged), *Butea frondosa* (winged), some species of *Dalbergia*, *Ougeinia dalbergioides*, *Robinia Pseudacacia*, and *Acacia Catechu*.

Some pods form rapidly and fall not long after the flowering, for example those of *Butea frondosa*, *Ougeinia dalbergioides*, *Erythrina* spp., *Bauhinia variegata*, *B. purpurea*, *B. refusa*, and *B. malabarica*. Others form rapidly and soon reach full size, but do not ripen for some time, and in some cases may hang long on the tree, for example those of *Dalbergia Sissoo*, *Pterocarpus* spp., *Hardwickia binata*, *Robinia Pseudacacia*, and *Albizzia* spp. A certain proportion of the pods are blown down during strong winds, dissemination of the seed being thus ensured, while in many cases the pods are scattered at various times and do not fall at once, a fact which will often ensure at least a certain proportion of the seed-crop falling under conditions favourable for reproduction.

The seeds of many leguminous species retain their vitality for some time, some hard seeds of acacias being known to remain fertile for several years. Many germinate very readily with sufficient moisture, but among these germination is frequently delayed until the second or even the third year,

particularly in the case of seed lying in the shade where the temperature is insufficient to stimulate activity; this is seen in *Cassia Fistula*, *Bauhinia malabarica*, *B. racemosa*, *Prosopis spicigera*, *Acacia arabica*, *Albizzia Lebbek*, *A. stipulata*, and *A. procera*. Some seeds germinate tardily owing to the existence of an impervious layer in the testa, and various measures have been suggested in order to hasten germination, for example burying the seeds for some time in moist manure, or soaking them for a short time in alcohol and then placing them for a time in water, the alcohol penetrating the impervious layer and the water subsequently penetrating it owing to the readiness with which it mixes with the alcohol, or cutting through the impervious layer with the smallest possible cut of a knife or file (see under *Caesalpinia digyna*): in the case of seeds of *Cassia Fistula* boiling them for about five minutes before sowing is reported to have given very good results.¹

In the descriptions of the various species dealt with below it will be seen that in the case of most species covering the seed with soil has a marked influence on successful germination. Seeds which germinate on the surface of the ground are liable to rot in damp localities, to dry up in dry weather, or to have their radicles destroyed by birds or insects, whereas seeds which have become covered with soil escape destruction from these causes. This explains to some extent the success with which reproduction of many species establishes itself on loose bare ground, where much of the seed becomes covered with earth or sand during the early showers preceding the monsoon.

As regards the artificial propagation of leguminous trees, a marked feature is the superiority of direct sowing over transplanting, and the superiority of line sowings over other forms of sowing because of the facility with which weeding and loosening of the soil can be carried out. Most species transplant with difficulty for forest purposes. Some can be transplanted with success after pruning down the stem and cutting off a portion of the taproot, whereas intact plants are very difficult to transplant; this is notably the case with *Dalbergia Sissoo*. Others cannot stand any pruning of the taproot, for example *Acacia Catechu* and *A. arabica*; transplanting of such species is particularly difficult. *Butea frondosa*, *Albizzia Lebbek*, *A. stipulata*, and *A. procera* can be transplanted either intact or after pruning the stem and root, though the latter method is preferable. Some species can be propagated by cuttings, for example *Erythrina*, *Robinia*, *Pongamia glabra*, *Adenanthera pavonina*, and others. *Amherstia nobilis* is usually propagated by layers.

Some leguminous trees produce root-suckers rarely or not at all, whereas others produce them with great freedom; among the latter are *Robinia Pseudacacia*, *Butea frondosa*, *Ougeinia dalbergioides*, *Dalbergia Sissoo*, *D. latifolia*, *Dichrostachys cinerea*, *Acacia dealbata*, *A. decurrens*, *Albizzia lucida*, *A. mollis*, *A. odoratissima*, and many others.

SUB-ORDER I. PAPILIONACEAE

Genera 1. OUGEINIA, Benth.; 2. BUTEA, Roxb.; 3. ERYTHRINA, Linn.; 4. PTEROCARPUS, Linn.; 5. DALBERGIA, Linn. f.; 6. PONGAMIA, Vent.; 7. ROBINIA, Linn.

¹ Forest Report, Bihar and Orissa, 1917-18.

1. OUGEINIA, Benth.

Ougeinia dalbergioides, Benth. Syn. *Dalbergia ougeinensis*, Roxb. Vern. *Sandan, chanjan, tinsa, tinas, pánan*, Hind. ; *Tiwas*, Mar.

A small to moderate-sized deciduous tree, often with a crooked stem. Leaves pinnately trifoliate. Crown full and rounded in well-developed trees. Bark up to 0.5 in. thick, ashy-grey or light brown with regular longitudinal and horizontal cracks, exuding a red gum when cut. The following are the average results of a number of measurements of bark thickness made in the Tirsal forest, Dehra Dun :

Girth of tree	0-6 in.	6 in.-1 ft.	1-2 ft.	2-3 ft.
Bark thickness	0.15 in.	0.27 in.	0.37 in.	0.4 in.

Wood, hard, close grained, strong and durable, much in request for agricultural implements, wheel-work, house-posts, and other purposes. In exceptional cases the tree attains a girth of 7 ft. and a height of 60 ft., but ordinarily it does not grow in any quantity to more than 4½ ft. in girth and 30-40 ft. in height.

DISTRIBUTION AND HABITAT. The sub-Himalayan tract and outer Himalayan valleys and slopes up to 5,000 ft., from the Punjab to Bhutan, Chota Nagpur, Central India, Orissa and the Circars, the Central Provinces, and Bombay. The tree occurs in parts of the Marwar state of Rajputana, but is of small size and is not abundant.

In the Peninsula it is found in mixed deciduous forest, where it is sometimes abundant and almost gregarious. In parts of the Central Provinces it reaches very fair dimensions with a straight clean bole. It is by no means exacting as to soil, and is found on a variety of geological formations, including shale, gneiss, trap, laterite, sandstone, quartzite, &c., and on a variety of soils, including black cotton soil, red clay, and gravel or boulder deposits, and will thrive on very poor ground, where, however, it does not attain large dimensions: on alluvial loam it attains a comparatively large size. It is very characteristic of landslips, banks, the sides of ravines, and other exposed places. In the Peninsula some of its more typical companions are *Terminalia tomentosa*, *T. belerica*, *Anogeissus latifolia*, *Lagerstroemia parviflora*, *Buchanania latifolia*, *Butea frondosa*, *Phyllanthus Emblica*, *Pterocarpus Marsupium*, *Dalbergia latifolia*, *Xylia xylocarpa*, and teak. In the sub-Himalayan tract and outer hills it is often found associated with the first seven of the foregoing species and also with sal, *Bauhinia* spp., and at higher elevations with *Pinus longifolia*. It is very common both in mixed deciduous forest and in sal forest: it ascends higher than most plains species, but at the higher elevations it is of small size. In its natural habitat the absolute maximum shade temperature varies from 100° to 115° F., the absolute minimum from 30° (sometimes less) to 45° F., and the normal rainfall from 35 (rarely less) to 70 in.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The old leaves are shed in January-February, turning yellow before falling, and the new leaves appear in March-April. The lilac or whitish flowers, in fasciated racemes, appear in February-March, and in the flowering season the trees are a conspicuous and beautiful sight. The pods (Fig. 103, a) form quickly, and ripen in May-June: they are 2-4 in. by 0.3 in., flat, jointed, light brown, with 2-5 seeds. The seeds

(Fig. 103, *b*) are 0.4–0.5 in. by 0.2–0.25 in., flat, reniform, light brown, with a thin testa and an even thinner papery tegmen. The pods fall chiefly in June–July : they are dehiscent during germination, but hardly before. Existing seed-year records show that the tree does not seed abundantly every year. Root-suckers of comparatively small size produce flowers and fruits.

GERMINATION (Fig. 103, *c–m*). Epigeous. If the seeds are extracted from the pods and sown separately, germination commences with the emergence of the radicle, the hypocotyl arching and drawing the cotyledons out of the ground. The testa is either left in the ground or carried up ; the inner papery tegmen is usually carried up, dropping on the expansion of the cotyledons. Under natural conditions the seeds ordinarily germinate within the pods or pod sections, which dehisce slightly and enable the radicle to push its way through between the valves. The shell of the pod may either be left in the ground, or, as is more frequent, may be carried up and dropped on the expansion of the cotyledons.

THE SEEDLING (Fig. 103).

Roots : primary root long, terete, tapering, wiry : lateral roots moderate in number, fibrous : nodules present. *Hypocotyl* distinct from root, 1.2–2 in. long, terete, tapering upwards, white turning green, tomentose, arched during germination. *Cotyledons* : petiole 0.05 in. or less : lamina 0.5–0.8 in. by 0.3–0.4 in., foliaceous, slightly plano-convex, somewhat fleshy, unequally ovate or reniform with an angular projection on the basal half of the incurved side, apex rounded, base obtuse, entire, green, glabrous. *Stem* erect, terete, zigzag at the nodes, green, young parts reddish, pubescent ; internodes 0.3–1 in. long. *Leaves*, first pair simple, opposite, subsequent leaves trifoliate, or sometimes one simple, alternate, at first small, succeeding leaves becoming larger. Stipules about 0.1 in. long, linear. Simple leaves with petiole 0.3–0.6 in. long, slender, channelled above, pubescent ; lamina 0.7–1.4 in. by 0.5–0.8 in., cordate or broadly ovate, acute, entire, glabrous above, pubescent on veins of lower surface, lateral veins 4–6 pairs. Trifoliate leaves with common petiole 0.7–3 in. long, channelled above, pubescent ; petiolules up to 0.1 in. long ; stipels less than 0.1 in., linear ; leaflets, terminal 1.2–3.5 in. by 0.8–2.4 in., lateral opposite, 0.6–2.5 in. by 0.5–1.5 in., broadly ovate, acute, entire, base obtuse, glabrous above, pubescent on veins beneath. Young leaves deep coppery red, older leaves green, paler beneath.

The seedling is of comparatively slow growth, the maximum height attained in beds which are weeded and watered being about 2 ft. in the first season, while under natural conditions the height attained is ordinarily about 3 to 6 in. in the same time. In their early stages the seedlings are tender to drought, and die off in quantity if exposed to a hot sun : they are also frost-tender. The development of the seedlings is better and mortality is less in slight shade, but in very heavy shade the seedlings do not survive. Weeding stimulates development ; a slight growth of weeds and grass does little or no harm, but heavy weeds kill off the seedlings. The taproot varies considerably ; as a general rule a long taproot is formed at an early stage, and may reach a length of 2 ft. within two months. The seedlings lose their leaves in January–February, and the new leaves appear in February–March. The young leaves are coppery brown in colour.

SILVICULTURAL CHARACTERS. The tree stands a fair amount of shade when young, and requires a certain amount of protection from the sun in its



FIG. 103. *Ougeinia dalbergioides*—SEEDLING $\times \frac{3}{8}$

a Fruits b—Seed c - g -Germination of seed extracted from pod
h - m Germination under natural conditions n - r Development of seedling to end of first season

early stages. Once it is established, however, it requires full overhead light for its best development. Although in early youth it is tender both to drought and to frost, it is afterwards hardy. In the abnormal drought of 1907 and 1908 in the forests of Oudh it proved to be decidedly hardy, as it did also in the severe frost of 1905 in northern India. It is much subject to browsing by cattle and deer. It coppices well and produces root-suckers in great abundance, particularly along steep banks and on hill-sides, where suckers may be seen issuing even from the joints on the sides of cliffs; on this account it is a useful tree for clothing unstable hill-sides. It suffers considerably from fire, and responds readily to fire-protection. As already mentioned, it is not exacting as regards soil, and will grow on decidedly poor ground. The root-system of the tree is characteristic: in addition to a taproot which is often twisted and branched, with numerous lateral rootlets for purposes of nutrition, there are superficial roots, often of great length and considerable thickness, spreading along or near the surface of the ground; roots of the former type have no buds, but those of the latter type, which are for propagation purposes, have numerous buds from which root-suckers are produced.

NATURAL REPRODUCTION. Under natural conditions the flat light pods are carried by wind to some distance from the tree immediately before and at the commencement of the monsoon, and germination takes place early in the rains. The seed germinates and the seedlings establish themselves best on bare loose ground, and for this reason profuse natural seedling reproduction often appears along the sides of roads, on ground exposed by landslips, and on cultivated ground even while the fields are still under cultivation. In the outer Himalaya and also in the Peninsula the sites of former fields are sometimes marked by dense crops of *Ougeinia*, which is one of the first species to make its appearance. Observations in experimental plots have shown (1) that on hard bare ground, where the seed germinates on the surface, great mortality occurs through drought, the radicles drying up before they can penetrate the soil; this is particularly the case in open places exposed to the sun; (2) that seed falling among weeds and grass, if these are at all dense, tends to rot before or during germination, and natural reproduction thus fails; in sunny places where the growth of weeds or grass is sufficiently scanty, these may be beneficial in affording protection from the sun; (3) that slight or moderate shade favours the germination and development of the seedlings by protecting them from the sun, but dense shade kills them off. As already mentioned, root-suckers form a very important means of reproduction, particularly on hill-sides and other places where the roots are exposed. Much of the reproduction found on deserted fields after temporary cultivation consists of root-suckers, probably from original seedlings which appear when the fields are under cultivation and survive the weeding and cutting back, which is often not intense.

In the forest pure natural crops of great density are often met with, sometimes under the light shade of other trees and sometimes in gaps in the forest crop. In the Tirsal forest, Dehra Dun, a dense mass of reproduction up to 4 ft. high in an area overrun by fire two years previously, and thus consisting of shoots two years old, contained 415 stems on an area of 318 square ft., or 56,800 per acre. Three years later the number of stems had been reduced

in the struggle for existence to 230, or about 31,500 per acre. Another plot in the same forest, estimated to be fifteen years old, contained about 11,500 stems per acre; the average height and girth were 16 ft. and 5.4 in. respectively.

ARTIFICIAL REPRODUCTION. Various experiments have been carried out at Dehra Dun in the artificial propagation of this tree. It was found that reproduction by stem cuttings gave indifferent results, while planting root cuttings was quite successful, a considerable proportion sending up suckers; the thicker root cuttings were found to produce more vigorous shoots than the thinner ones. As regards reproduction by seed, the best results were obtained by line sowings with regular weeding, 1 lb. of pods being required for 300 ft. of line. These sowings, carried out with the aid of field crops, proved very successful. The whole ground was ploughed up, the pods being sown shortly before the break of the monsoon in lines 10 ft. apart; the lines were kept clear of field crops to a width of 2 ft., the crops being sown in the spaces, 8 ft. wide, between the lines. The crop employed was the lesser millet or *mandwa* (*Eleusine coracana*), which was found to give such dense cover as to suppress the seedlings if sown continuously over the area. The crops may be cultivated for one, two, or even three seasons, and while the area is under cultivation the lines of seedlings are weeded by the cultivator. Ordinary line sowings without field crops on lines well ploughed to a width of 1½ ft. also proved successful, provided regular weeding was carried out.

Transplanting from the nursery has also proved moderately successful, provided young plants are used before they have developed long taproots. The pods should be sown in the nursery in May or early June in drills 9 in. apart and lightly covered with earth, the beds being regularly watered: the seedlings should be transplanted early in the rains, while still only a few inches high. Direct sowing, however, is so much more successful than transplanting that the latter is not to be recommended on a large scale.

RATE OF GROWTH. It is impossible to ascertain the rate of growth from annual rings as these are not distinct. Sample plot measurements indicate a comparatively slow rate of growth. In the United Provinces measurements in nine sample plots in four forest divisions gave the following results:

Ougeinia dalbergioides: measurements in high forest sample plots,
United Provinces.

No.	Forest division.	Number of years under observation. years.	Girth classes.	Mean annual girth increment for the period.
			ft.	in.
1	Saharanpur	12	0-1	0.41
			1-2	0.22
			2-3	0.20
2	Dehra Dun	10	1-2	0.54
3	Lansdowne	17	1½-3	0.13
4	"	15	1½-3	0.43
5	"	13	1½-4½	0.43
6	"	7	1½-3	0.39
7	"	5	1½-4½	0.27
8	Ramnagar	19	1½-3	0.29
9	Haldwani	11	1½-4½	0.52

As regards coppice, measurements made in 1910 by Mr. C. M. McCrie in

the Gorakhpur district, United Provinces, gave the following results for *Ougeinia* as compared with sal :

Ougeinia dalbergioides : rate of growth of coppice, Gorakhpur.

Age. years.	Mean height.		Mean girth.	
	<i>Ougeinia</i> . ft.	Sal. ft.	<i>Ougeinia</i> . in.	Sal. in.
2	3.0	3.0	—	—
4	5.2	7.0	1.6	2.0
6	7.0	10.3	2.2	2.9
8	8.3	13.0	2.7	3.8
10	9.5	15.3	3.2	4.8
12	10.3	17.5	3.6	5.8
14	11.2	19.2	3.8	6.7
16	11.8	20.9	4.0	7.5

Measurements made in 1916 in the Saitba coppice coupes, Kolhan, Bihar and Orissa, on poor hilly ground, gave the following results :

Ougeinia dalbergioides : rate of growth of coppice, Saitba.

Age. years.	Mean height.		Age. years.	Mean height.	
	ft.	in.		ft.	in.
2	3.5	1.5	10	14.0	6.2
4	7.0	3.2	12	15.5	6.9
6	10.0	4.3	14	17.0	7.5
8	12.0	5.3			

2. BUTEA, Roxb.

Butea frondosa, Roxb. Vern. *Dhák*, *palás*, *kakria*, *chalcha*, Hind. ; *Muttuga*, Kan. ; *Parás*, *palás*, Mar. ; *Parasu*, Tam. ; *Modugu*, Tel. ; *Pauk*, Burm.

A moderate-sized deciduous tree, with a rather crooked irregular trunk and branches and a somewhat open crown, with large trifoliate leaves. Bark moderately thick; fibrous, grey or light brown, exuding a red juice when cut. The tree sometimes reaches a fairly large girth ; Mr. A. E. Wild records one of 12 ft. 9 in. in Palamau. The wood is not of much value as timber, but is fairly durable in contact with water, and is used for well-curbs, water-scoops, &c. The chief use of the tree is for the propagation of lac, in which respect it ranks second only to *Schleichera trijuga* among the trees of India. The leaves are lopped for buffalo fodder, and are used as plates, the bark, particularly that of the roots, gives a coarse fibre, and the red juice which exudes from cuts in the bark hardens into a red astringent gum known as 'Bengal kino', used in medicine. Silviculturally the tree is of importance as being one of the commonest trees of the plains of India, and as being capable of thriving on saline soils and badly drained ground where most species will not grow.

DISTRIBUTION AND HABITAT. Common throughout the greater part of India and Burma, ascending the outer Himalaya to about 3,000 ft. or occasionally higher, the Khandesh Akrani to 3,700 ft. (Talbot), and the hills of southern India to 4,000 ft. : rare or absent in the most arid regions. The tree is very typical of open grass-lands, where it is frequently gregarious, as in the *tarai* country of northern India. It grows in water-logged situations, on black cotton soil, and even on saline soil. It is a characteristic tree on the plains of India, often forming pure patches in grazing grounds and other open places, escaping extermination owing to its immunity from grazing, and its power of reproduc-

tion from seed and root-suckers and of recovery from the effects of constant lopping. It is common in certain types of mixed deciduous forest of an open character; in parts of the Central Provinces, for example, a common type is that in which it occurs mixed with *Terminalia tomentosa*, *Diospyros Melanoxylon*, *Acacia Catechu*, and *A. leucophloea*. In Burma it is most characteristic of open lower mixed or savannah forests, associated with *Stephegyne parvifolia*, *Dalbergia cultrata*, *D. purpurea*, *Careya arborea*, *Anogeissus acuminata*, *Terminalia pyrifolia*, and other trees growing in extensive tracts of savannah grass, where it also frequently occurs pure or nearly so. Bourdillon says that in Travancore it is confined to the drier parts of the country, where it is found growing in grass-land up to 4,000 ft.

In the natural habitat of the tree the absolute maximum shade temperature varies from 100° to 120° F., the absolute minimum from 25° to 60° F., and the normal rainfall from 25 to 180 in. or more.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The leaves begin to fall at the end of November or during December, and by the end of January some trees are leafless or nearly so; others may retain their leaves, particularly on the lower branches, during the flowering season, up to the end of March. The new leaves appear in April or early May, and are of a delicate fresh green colour. The blackish flower-buds appear on the bare branches in January, and from the end of that month and through February and March the trees herald the hot weather by bursting forth in a blaze of scarlet blossom, presenting a gorgeous sight which if once seen can never be forgotten: the tree is on this account appropriately termed the 'flame of the forest'. At the time of flowering the trees are either entirely leafless or the leaves may linger on the lower branches, the flowers chiefly covering the upper part of the tree. Flowering continues, according to locality, until the end of March or the end of April. Seasonal conditions influence the time of flowering to a considerable extent; it takes place earlier than usual in dry seasons.

The fruit forms very rapidly, the scarlet flowers quickly giving place to pale green flat pods, which often attain a length of 2 to 3 in. before all the flowers have fallen. In April the leafless trees are often covered with the flat green pods, and appear as if in full foliage. The pods (Fig. 104, *a*) ripen in May-June, and fall soon after ripening, being blown to some distance from the trees by the stiff breezes which are common at that time. The pods when ripe are greyish yellow, 4-8 in. by 1.4-1.8 in., ligulate, pendulous, firm, silky tomentose, with one seed near the apex; the pod is dehiscent at the apex during germination. The seed (Fig. 104, *b*) is flat; reniform, 1.3-1.5 in. by 0.9-1 in., with a thin papery reddish brown testa. Tests carried out at Dehra Dun have shown that the seed loses its vitality within a year, but fresh seed has a very high germinative power.

GERMINATION (Fig. 104, *c-f*). Hypogeous. The seed does not escape from the pod: the latter dehisces at the apex, and the emergence of the radicle and plumule is effected by the development of short cotyledonary petioles. The cotyledons remain attached to the seedling for a considerable time after germination.

THE SEEDLING (Fig. 104).

Roots: primary root long, very thick, fleshy, terete, tapering, pale yellow



FIG. 104. *Butia frondosa* SEEDLING $\times \frac{1}{2}$
 a Fruit (seed at left extremity) b Seed c-e Germination stages
 f—Seed removed from pod to show germination g, h Early development of seedling

at first, becoming brown, pubescent when young : lateral roots moderate in number, fibrous, pubescent when young, distributed down main root. *Hypocotyl* very short and scarcely distinguishable. *Cotyledons* subterranean : petiole 0.5–0.7 in. long, fleshy, flattened, glabrous, curving to side of stem : lamina 1.1–1.6 in. by 0.9–1.1 in., flat, fleshy, reniform, yellow. *Stem* erect, terete, green, tomentose ; first internode, between cotyledons and first pair of opposite leaves, 3–5 in. long, subsequent internodes much shorter. *Leaves*, first pair simple, opposite, subsequent leaves trifoliate, alternate. Stipules 0.1–0.15 in. long, sub-falcate or triangular acuminate, tomentose. Stipels of compound leaves 0.1–0.15 in., triangular or linear acuminate, tomentose. Simple leaves with petiole 0.15 in. long, thick, terete, tomentose ; lamina 2.5–5 in. by 2.5–4.5 in., broadly or obliquely ovate or rhomboidal, obtuse or acute, mucronate, entire, pubescent, venation arched reticulate, lateral veins 6–9 pairs. Trifoliate leaves with common petiole 2–5 in. long, green, pubescent. Leaflets with thickened petiolules 0.15–0.2 in. long, tomentose. Terminal leaflet 2.5–5 in. by 2–4 in., rhomboidal ovate or obovate, acute or obtuse, mucronate ; lateral leaflets opposite, 1.5–4.5 in. by 1–3 in., unequally ovate, acute or obtuse, mucronate ; all leaflets entire, glabrous or slightly pubescent above, pubescent beneath, lateral veins 5–9 pairs.

The development of the seedling varies greatly according to the conditions under which it grows. It is capable in the first season of struggling against heavy weed-growth, but continued suppression of this kind kills it within the next year or two. On stiff ground also the development is slow, although the seedling is capable of surviving. Weeding and irrigation greatly stimulate the growth, the former being even more important than the latter. Experiments at Dehra Dun showed that under ordinary natural conditions a height of about 4–6 in. is attained by the end of the first season ; on stiff ground or among comparatively heavy weeds the subsequent growth may amount to only one or two inches a year. The effects of weeding and irrigation are illustrated by the following figures of growth in experimental plots at Dehra Dun :

Maximum height of *Butea frondosa* seedlings at end of first three seasons, Dehra Dun.

End of season.	Irrigated.		Not irrigated.	
	Weeded.	Not weeded.	Weeded.	Not weeded.
	ft. in.	ft. in.	ft. in.	ft. in.
1st	2 2	1 2	1 8	0 5
2nd	8 0	2 6	4 6	0 10
3rd	12 9	3 0	8 10	1 7

(plants weakly)

The seedling develops a very long taproot at an early stage, a length of as much as 2 ft. being sometimes attained in three months, and 4½ ft. by the end of the first season. The upper part of the taproot is thick and fleshy for several inches from the top, attaining a diameter of 1–1.7 in. Except under favourable conditions the seedlings die back for some inches from the top or down to ground-level either in the cold season (if due to frost) or in the hot season (if due to drought), new shoots being sent up subsequently. This dying back may continue for two or three successive years or more, until the plants become sufficiently established to send up permanent shoots. In the case of vigorous plants in irrigated or weeded sowings this dying back does not take place, but it occurs very commonly in the case of transplants, among heavy weeds, in frosty localities, in dry climates or situations, and on stiff soils.

The thick fleshy taproots are readily devoured by rats, which burrow underground and attack them, or by pigs and porcupines, which grub them up. The roots, however, have wonderful power of recovery, and unless almost entirely eaten away they will send up new shoots from the portions left untouched. Line sowings at Dehra Dun were thinned out by driving a long knife down through the taproots and severing them as low down as possible, the plants being then pulled up, but all the pieces of root remaining in the ground subsequently produced vigorous shoots. This power of recovery is noticeable in the case of certain other species with thick fleshy roots, for example *Bombax malabaricum* and *Hymenodictyon excelsum*. It renders the seedlings particularly hardy, for although they are liable to be killed back by frost and drought they almost invariably produce new vigorous shoots from the base. The seedlings are avoided by cattle and goats.

The leaves of seedlings drop about January to March: new growth starts in March–April, or sometimes not till May.

SILVICULTURAL CHARACTERS. Although it grows typically in open places, the tree is capable of standing a fair amount of shade. In its natural habitat it is frost-hardy; in severe frosts, as in that of 1905 in northern India, the leaves shrivel up and fall, but as a rule little or no permanent damage is done. The tree is very drought-resistant, as was proved in the abnormal drought of 1907–8 in the forests of Oudh, and in that of 1899–1900 in the Indian Peninsula, when young plants of this species were almost the only ones which escaped in the worst affected areas. The leaves are not browsed by cattle or goats, and for this reason the tree is favoured in heavily grazed areas, where it may form pure masses, particularly on black cotton soil. The tree coppices and pollards well, and produces root-suckers freely: the results of pollarding experiments for lac cultivation are given below.

NATURAL REPRODUCTION. The seeds germinate early in the rainy season not long after the fall of the pods; at this time numerous young seedlings with pods still attached may be found in the neighbourhood of the trees. If moisture is plentiful and sustained, germination takes place without difficulty in the case of pods lying on the surface of the ground, but if there is only occasional rain with intervening dry weather, inducing the swelling of the seed without complete germination, the seed is liable to rot or to dry up. If the pods become buried with the early showers, as they often do in loose soil, successful germination is greatly facilitated. Natural reproduction, both by seed and by root-suckers, is more profuse than in the case of most species on the plains of India, owing to the hardiness of the seedlings, their power of recovery from injury, and their immunity from damage by grazing.

ARTIFICIAL REPRODUCTION. Experiments carried out at Dehra Dun have shown that artificial reproduction may be effected successfully both by direct sowing and by transplanting from the nursery, though the former is undoubtedly the more successful and economical method. In forest operations the young plants suffer greatly from the attacks of pigs and porcupines, and of rats on grass-lands. In places where these animals are prevalent it is almost hopeless to attempt raising plantations of *Butea* unless some means of preventing their depredations can be applied.

Direct sowing. The tree can be raised with great success by line sowings,

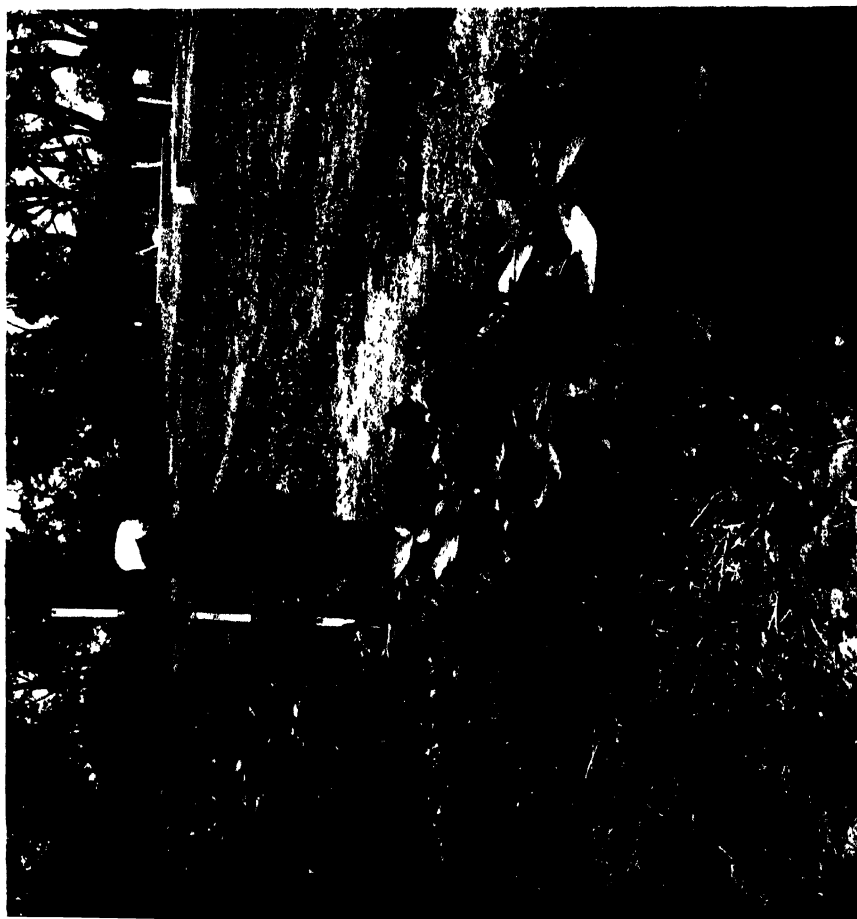


FIG. 105. *Butea frondosa*, irrigated line sowings 6 months old, Dehra Dun.
Staff shows feet.



FIG. 106. *Butea frondosa*, line sowings with the aid of field crops, Dehra Dun, showing plants in second season. Line left unweeded in first year and weeded in second year, crops (lesser millet) being resown. Staff shows divisions of six inches.

watering and weeding should be carried out after sowing: the seedlings usually commence to appear in one to two weeks.

POLLARDING FOR LAC CULTIVATION. I recently published details of experiments carried out from 1909 to 1918 at Ranipur in the Saharanpur Siwaliks, the object of which was to ascertain the best method of pollarding *Butea frondosa* trees, and the most suitable rotation to adopt, for the purpose of propagating lac.¹ For the reception of lac it was found that complete pollarding was far preferable to the partial lopping so frequently practised, since not only does it produce a larger number of succulent shoots such as are required to support the lac insect, but the collection of the lac crop is greatly facilitated if all the shoots are lopped off at one time, as this obviates the waste of time, under a system of partial lopping, in searching for lac-covered branches and twigs. The tying up of brood-lac is also much facilitated by complete pollarding, since clusters of pollard-shoots are produced, at the base of which it is easy to place open baskets full of brood-lac for the impregnation of the shoots.

The initial pollarding of trees which have not previously been pollarded should be carried out with a saw, all branches being cut off to a section of about 2 to 4 in. in diameter, and no leafy branches being left: it is not advisable, if it can be avoided, to cut branches of a larger diameter than 4 in., otherwise thick corky pollard-shoots are produced which are avoided by the lac insects. The branches should not all be cut off flush, but occasional stumps about 6 to 8 in. long should be left where required, to facilitate climbing during subsequent pollarding operations. The subsequent pollarding, at the time of collection of the lac crop, should be done with a sharp bill-hook or light axe, the shoots being cut off flush at the base: the pollarding should be complete, no shoots being left on the tree.

As regards the pollarding rotation, the experiments proved conclusively that a rotation of one year is the only satisfactory one to adopt. At Ranipur the swarming of the lac larvae takes place twice a year, early in July and late in October. The trees are pollarded immediately before the swarming and a portion of the lac crop then gathered is used as brood-lac for the next crop. The brood-lac consists of lac-covered twigs cut into pieces several inches long, which are placed in open-work baskets, a number of pieces in each. The baskets of brood-lac are placed or hung up with wire hooks at the bases of the clusters of pollard-shoots produced by the previous lopping; the lac larvae soon swarm over the shoots, after which the baskets of lac are removed. The lac larvae always swarm over the young green portions of the shoots and on the petioles and midribs of the leaves, never on those portions of the shoots which have begun to form corky bark. In the case of the more vigorous shoots this corky bark often begins to form in less than half a year, while in shoots more than a year old the length of new green growth each year is much smaller than it is in pollard-shoots of the first year: consequently with any lengthening of the rotation above one year there is a considerable diminution of the lac-bearing surface on each tree, while in addition the total number of trees available for the reception of lac on a given area is reduced. It follows, therefore, that a pollarding rotation of one year produces a higher yield of lac than any longer rotation.

¹ Ind. Forester, xlv (1919), p. 223.

In carrying out annual pollarding in practice the trees on a given area should be divided into two groups ; in one group the trees are lopped in July and the pollard-shoots are ready for the reception of brood-lac the following October, while in the other group they are lopped in October for the reception of brood-lac the following July. These dates refer to the locality in which the experiments were carried out, and may require modification to suit other localities.

The effect of the annual pollarding on the vigour of the trees and the pollard-shoots was observed for ten years. There was considerable variation in the number and dimensions of the shoots from year to year, but the average results showed no great diminution in their vitality during the period in question. It may, therefore, be concluded that annual pollarding can be carried out with little or no deterioration in the pollarding capacity of the trees for a number of years, though in practice two safeguards should be adopted, namely : (1) to fix a limit of girth, to be ascertained locally, below which no trees should be pollarded ; and (2) to fill up all gaps artificially with young plants. Possibly a minimum girth of $1\frac{1}{2}$ or 2 ft. will suffice generally. At Dehra Dun young *Butea frondosa* plants in weeded line sowings may be expected to attain girths of $1\frac{1}{2}$ ft. in nine years and 2 ft. in twelve years if irrigation is carried out, and girths of $1\frac{1}{2}$ ft. in eleven years and 2 ft. in fifteen years without irrigation. These experiments showed that the yield of lac was greater in the case of trees growing in open positions than of those growing close together, and hence tending operations should include the thinning out of trees where they are crowded.

During the course of these experiments an effort was made to ascertain if steps could be taken to eradicate the various parasitic and predaceous insects which do so much damage to the lac and may destroy the entire crop. Careful observations of the dates of emergence of these insects from samples of lac collected at different times showed that their emergence takes place for the most part shortly after the swarming of the lac larvae in July and October. It was hoped, therefore, that the prompt removal of the brood-lac as soon as the swarming of the lac larvae was over would result in a diminution in the number of parasitic and predaceous insects, and possibly in their extermination, and actually such a course must result in the destruction of large numbers of these insects if precautions are taken to remove all the lac in closed bags. A further precaution would be to collect and burn all twigs from which the lac crop has been gathered and which usually have fragments of lac adhering to them, as well as the leaves, which fall about January to March, since their petioles and midribs are frequently coated with half-formed lac. Actually such a course did not result in any appreciable diminution in the number of parasitic and predaceous insects, though this may well have been accounted for by the fact that indiscriminate lac cultivation is carried on in the neighbourhood, and each brood of lac was probably parasitized afresh from outside. Such a contingency would nullify any efforts to cope with these insects under a system of regular pollarding, which, in order to have a reasonable chance of success, would require to be adopted universally in a given locality.

RATE OF GROWTH. So-far as available records show the rate of growth of coppice-shoots is fairly rapid, but the girth increment of trees is decidedly

slow. Measurements in different coppice coupes near Dehra Dun recorded by Mr. A. F. Broun in 1886 gave the following results in the case of *Butea* as compared with sal in the same coupes :

Age		8 yrs.	8 yrs.	9 yrs.	9 yrs.	10 yrs.
		ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
Mean height	{ <i>Butea</i>	17 0	17 0	15 0	14 2	8 0
	{ Sal	16 3	13 2	13 5	16 0	11 11
Mean girth	{ <i>Butea</i>	0 8	0 7.1	0 13.5	0 9.4	0 2
	{ Sal	0 8.3	0 7.1	0 8.7	0 8.6	0 5.9

The locality in question is subject to severe frost, which may account for the small size of the shoots in the ten-years coupe if the shoots had been killed back at some period.

The girth increments of trees are exhibited in the following records of periodical measurements in sample plots in the United Provinces :

Butea frondosa : rate of growth of trees, United Provinces.

Locality.	Number of years under observation.	Number of trees.	Girth class. ft.	Mean annual increment for period. in.	Remarks.
Saharanpur division (Dholkhand, Lakarkot, and Maluwala—3 plots) .	4, 7, and 12	7	{ 1-2 2-3 3-4	{ 0.10 0.09 0.16	In sal forest.
Saharanpur division (Ranipur)	3	10	1-2	0.27	In fairly open situation.
Lansdowne division (3 plots)	4, 4, and 17	6	1½-3	0.45	

Under favourable conditions seedlings and saplings grow rapidly, and it is probable that tended plantations would show a very fair rate of growth for some years at least. In irrigated and unirrigated line sowings at Dehra Dun dominant plants seven years old had attained the following girths :

	Irrigated.	Unirrigated.
	ft. in.	ft. in.
Mean girth	1 4	1 1
Maximum girth	1 11	1 3

3. ERYTHRINA, Linn.

This genus comprises seven Indian species with large trifoliate leaves and bright red flowers which in most cases appear in the early part of the hot season when the trees are leafless. Of the Indian species all are trees except *E. resupinata*, Roxb., a dwarf herbaceous species with a perennial root-stock from which are sent up annually racemes of scarlet flowers in the hot season, the leafy shoots appearing subsequently and dying down after the rainy season ; this interesting plant occurs in the annually burnt grass-lands of the sub-Himalayan tract, and the flowers are conspicuous on the ground after the annual fires have overrun these savannah lands.

The tree species have light soft whitish woods which are used for sieve-

frames, scabbards, domestic utensils, and other purposes. Silviculturally they are interesting from the readiness with which they grow from cuttings, fairly large branches if stuck in the ground taking root and growing rapidly : these cuttings are grown sometimes for live fences and often for supporting betel vines. Some of the species are planted for ornament.

Species 1. *E. suberosa*, Roxb.; 2. *E. indica*, Lam.

1. *Erythrina suberosa*, Roxb. Vern. *Pangra*, *dhauldhak*, Hind. ; *Kathit*. Burm.

A moderate-sized to large deciduous tree with thick corky light grey bark, armed with conical prickles. The tree is scattered in dry forests throughout India and Burma. The trees are leafless as a rule from December to June. The scarlet flowers appear from March to May on the leafless trees, and the pods ripen about June-July. The seedling forms a long very thick taproot, as much as 1 in. in diameter in the first season, like that of *Butea frondosa*. The tree coppices and pollards vigorously, thick prickly shoots being produced ; it also grows readily from cuttings. The growth is rapid ; a cross-section in the silvicultural museum at Dehra Dun showed 42 rings for a girth of 5 ft. 3 in., giving a mean annual girth increment of 1.5 in. Gamble's specimens showed 4 rings per inch of radius, representing a mean annual girth increment of 1.57 in.

2. *Erythrina indica*, Lam. Indian coral tree. Vern. *Pangra*, Hind., Mar. ; *Pinlè-kathit*, Burm.

A moderate-sized tree with small black prickles and smooth greenish yellow bark exfoliating in papery flakes. Indigenous in the coast forests from Bombay to Malabar, from the Sundarbans along the coast through Arakan, Pegu, and Tenasserim, and in the Andamans and Nicobars : much planted for ornament, and sometimes escaped from cultivation. The tree occurs chiefly along raised sandy beaches above high-water mark : in the Andamans its chief associates on these beaches are *Mimusops littoralis*, *Calophyllum Inophyllum*, *Thespesia populnea*, *Terminalia Catappa*, *Heritiera littoralis*, *Azelia bijuga*, *Pongamia glabra*, and *Hibiscus tiliaceus*. Talbot says that on the Bombay coast it is sometimes associated with *Calophyllum Inophyllum*, *Salvadora persica*, *Clerodendron inerme*, *Grewia Microcos*, and other species. The scarlet flowers appear in April-May, and the pods ripen about June.

4. PTEROCARPUS, Linn.

This genus comprises five species in the Indian region, namely : (1) *P. Marsupium*, Roxb., the kino tree, extending throughout the greater part of the Indian Peninsula and northward to the foot of the central Himalaya ; (2) *P. santalinus*, Linn. f., the red sanders, occupying a restricted area in the Indian Peninsula ; (3) *P. dalbergioides*, Roxb., the Andaman padauk or redwood, indigenous in the Andaman Islands ; (4) *P. macrocarpus*, Kurz, the true or Burma padauk, occurring as a forest tree throughout the greater part of Burma ; and (5) *P. indicus*, Willd., the Malay padauk, believed to be indigenous in the Malay Peninsula and Archipelago, and commonly planted along roadsides in Rangoon and other towns in Burma. Of these the first four are important timber trees, while the fifth is a well-known roadside tree in Burma, but is of no importance as a timber tree in that province.

Until Col. Prain published in 1900 his 'Report on the Indian Species of *Pterocarpus*' (*Indian Forester*, xxvi, App.) much confusion existed regarding the identity of the trees to which the name 'padauk' has been given; his paper set at rest the misapprehensions previously existing, and established the fact that there are three distinct species popularly known as 'padauk'. Strictly speaking *P. macrocarpus*, Kurz, indigenous in Burma, is the true padauk tree; the name was applied to the Andaman tree, *P. dalbergioides*, Roxb., by Burmese convicts owing to its resemblance to the padauk tree of their country, while the same name was also given to the introduced tree *P. indicus*, Willd., owing to its general similarity to the wild padauk of Burma.

The trees of this genus are characterized by alternate compound leaves with alternate leaflets, yellow flowers in racemes, usually paniced, and flat orbicular indehiscent one- or two-seeded pods, of which the hard bony centre containing the seeds is surrounded by a wide circular wing. The seeds of all the species have a characteristic shape to which in the descriptions below the term 'dolabriform' is applied as most nearly describing it; the outline resembles that of a broad curved pruning-knife, or a triangle with one short side and two longer unequal sides, the longer of which is concave. Germination is similar in all the species, the radicle (or where there are two fertile seeds two radicles) issuing from the side of the pod opposite the stalk and the pod dehiscing slightly at the point of emergence; this point is strictly speaking the side and not the end of the pod, for as the pod develops from the flower one side grows, faster than the other, so that the end is bent round to one side in the fruit and the style is apparently lateral and in some cases quite near the stalk itself.

The members of this genus are essentially trees of warm climates; the hardiest of the Indian species is *P. Marsupium*, which extends to localities where frost is not unknown, and is the only species which has been able to survive the winter at Dehra Dun. The most deciduous species is *P. macrocarpus*, which is leafless for an appreciable length of time; the others are either not leafless for so long or are semi-deciduous or practically evergreen. The four strictly Indian species are not gregarious trees, but occur scattered in mixed, usually deciduous forests, where as a rule they form a comparatively small proportion of the growing stock; they are found most typically on undulating or more or less hilly country, avoiding stiff low-lying clayey ground and requiring perfect drainage.

Species 1. *P. Marsupium*, Roxb.; 2. *P. santalinus*, Linn. f.; 3. *P. dalbergioides*, Roxb.; 4. *P. macrocarpus*, Kurz; 5. *P. indicus*, Willd.

1. ***Pterocarpus Marsupium***, Roxb. Kino tree. Sans. *Asana*. Vern. *Bija*, *bijasál*, *piasál*, Hind.; *Bibla*, *asan*, Mar.; *Honne*, Kan.; *Yegi*, *peddagi*, Tel.; *Vengai*, Tam.; *Bange*, Coorg.

A large deciduous tree with spreading branches, producing a straight clean bole under favourable conditions. Leaves 7-9 in. long with 5-7 (sometimes 8?) coriaceous leaflets. Bark about 0.5 in. thick, grey, exfoliating in small irregular scales; blaze pink with whitish markings, that of older trees exuding a blood-red astringent gum-resin. One of the most important timber trees of the Indian Peninsula, attaining under favourable conditions a height of 100 ft. and a girth of 8 ft. or more. Wood very hard, close grained, heart-

wood yellowish brown, durable, much used for building, agricultural implements, carts, wheel-work, boats, &c. ; the wood stains yellow when damp. The red gum-resin which exudes from wounds in the bark furnishes the ' kino ' of commerce, a valuable astringent used in medicine. Prain distinguishes two rather marked botanical varieties of the tree, each containing two somewhat distinct geographical forms.

DISTRIBUTION AND HABITAT. Throughout the greater part of the Indian Peninsula, extending northward to Mount Abu in the west, the Santal Parganas in the east and Bundelkhand in the centre : also in limited quantity in the sub-Himalayan tract, in Oudh, and the Kumaun *bhabar*. In Ceylon it is found in the central parts of the island (Prain). The tree is found scattered in deciduous forests, mainly on hilly ground, at elevations up to 3,500 ft. or sometimes more, but most commonly between 500 and 1,500 ft. In the Central Provinces it is fairly common in Bhandara, Balaghat, Saugor, Chanda, and Damoh, and is more or less scattered or locally common in other districts, but is rare in Berar ; it occurs mainly on hilly ground, preferring northerly aspects, its chief companions being teak, *Terminalia tomentosa*, *T. belerica*, *Buchanania latifolia*, *Lagerstroemia parviflora*, *Anogeissus latifolia*, *Acacia Catechu*, *Cleistanthus collinus*, *Butea frondosa*, *Dalbergia latifolia*, and other trees characteristic of the mixed deciduous forests. In Chanda it attains large dimensions. In Bombay it occurs most plentifully in the southern portion of the Presidency, being particularly common in North Kanara and fairly plentiful in Surat and in the Rajpipla state. In the moist climate of North Kanara it affects chiefly the upper parts of ridges where it obtains light and warmth ; its chief associates here are teak, *Dalbergia latifolia*, *Xylia xylocarpa*, *Lagerstroemia lanceolata*, *Terminalia tomentosa*, *T. paniculata*, and *Adina cordifolia*. In the Deccan districts it is more scattered ; in the Khan-desh Akrani it ascends to 3,700 ft. (Talbot). In southern India it occurs in most districts, scattered in deciduous forests associated with teak, *Terminalia tomentosa*, *T. Chebula*, *Dalbergia latifolia*, *Chloroxylon Swietenia*, *Anogeissus latifolia*, *Albizia Lebbek*, *A. odoratissima*, *Diospyros Melanoxylon*, and other trees, with or without bamboos. In the Nilgiri Wynaad it may in favourable localities form as much as 10 per cent. of the growing stock. It attains its largest dimensions in the south, particularly in Coimbatore, Madura, and Tinnevely, where trees up to 16 ft. in girth are occasionally met with. In the region of *Pterocarpus santalinus*, that is, chiefly in Cuddapah and North Arcot, the two species occur together, but whereas *P. santalinus* ascends to 3,000 ft. *P. Marsupium* ascends only to 2,500 ft. In the northern parts of the Presidency where, in Ganjam, it is sometimes found in sal forest, it seldom attains large size. In Coorg and Mysore it is common in deciduous forests, and reaches large dimensions. In Travancore it is common in deciduous forests up to 3,500 ft. (Bourdillon). It is one of the most important timber trees of Hyderabad.

In Chota Nagpur and Orissa it is locally common, chiefly on hilly ground in valleys or on northerly slopes, in mixed deciduous forest or in sal forest. Except in parts of Orissa, Sambalpur, and Singhbhum it is usually of small size. In the United Provinces it occurs in limited quantity and of comparatively small size in parts of Bundelkhand and in the sub-Himalayan tract from

Goorakhpur westward to the eastern corner of the Kumaun *bhabar* tract, in dry deciduous forest associated with *Lagerstroemia parviflora*, *Terminalia tomentosa*, *Anogeissus latifolia*, *Holoptelea integrifolia*, *Acacia Catechu*, and other trees. It is absent from the Bengal Duars. It is found scattered in limited quantity and of small size in parts of the Marwar, Rewah, Indore, and Gwalior states.

The tree is characteristic of deciduous types of forest, and appears to grow on a variety of formations provided the drainage is good. It grows both on hilly or undulating country, and on more or less flat ground, preferring a soil with a fair proportion of sand, and is often found on red loam with a certain percentage of clay. It is not exacting, however, since it reaches larger dimensions than most other trees on exposed hill-sides on rocky ground and shallow soil where the forest growth is poor: in such places it is at times almost gregarious. In the Peninsula it is common on gneiss, quartzite, shale, conglomerate, sandstone, and laterite: less common on trap (Haines). In the sub-Himalayan *bhabar* tract it occurs on a deep dry well-drained boulder formation where the subsoil water-level is at a great depth. Foulkes (*Notes on Timber Trees of S. Canara*) says it grows on laterite when there is plenty of moisture in the soil, and will grow well on rocky laterite; also that it is well suited to gneissic soils, but will not grow on the sandy soils of the coast.

In its natural habitat the absolute maximum shade temperature varies from 95° to 118° F., the absolute minimum from 32° to 62° F., and the normal rainfall from 30 to 80 in. or more.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The tree is nearly ever-green, or is leafless for a very short time in the hot season in April–May, the new leaves appearing in May–June. The panicles of fragrant yellow flowers appear from June to September, sometimes later. In the Peninsula the pods ripen from December–January until March–April. In the sub-Himalayan tract they are not ripe till about April. The pods (Fig. 108, *a*) are light yellowish brown, nearly orbicular, 1–2 in. in diameter, the wing flat and stiff, and the central portion, containing one to two seeds, convex and bony. The seeds (Fig. 108, *b*) are dolabriform, 0.4–0.5 in. long, reddish brown, fairly hard, with a smooth shiny leathery testa. The ripe pods hang in clusters on the tree for some time after ripening, most of them falling during and towards the end of the hot season, the strong dry winds prevalent in many localities at that time distributing them to a distance. In good seed-years, which occur at frequent intervals, the pods are produced in great abundance, particularly by trees in open situations; the seeds, however, possess a comparatively low percentage of fertility, and are sometimes much affected by insect attacks.

GERMINATION (Fig. 108, *c-g*). Epigeous. One or sometimes two seedlings are produced from one pod. The radicle emerges from the side of the pod opposite the stalk, at once bending downwards to reach the soil. Either the cotyledons are extricated by the arching of the hypocotyl, the pod being left on or in the ground, or the pod enclosing the cotyledons is raised above ground, falling with the expansion of the cotyledons. The testa of the seed remains within the pod.

THE SEEDLING (Fig. 108).

Roots: primary root long, moderately thick, terete, tapering, wiry to

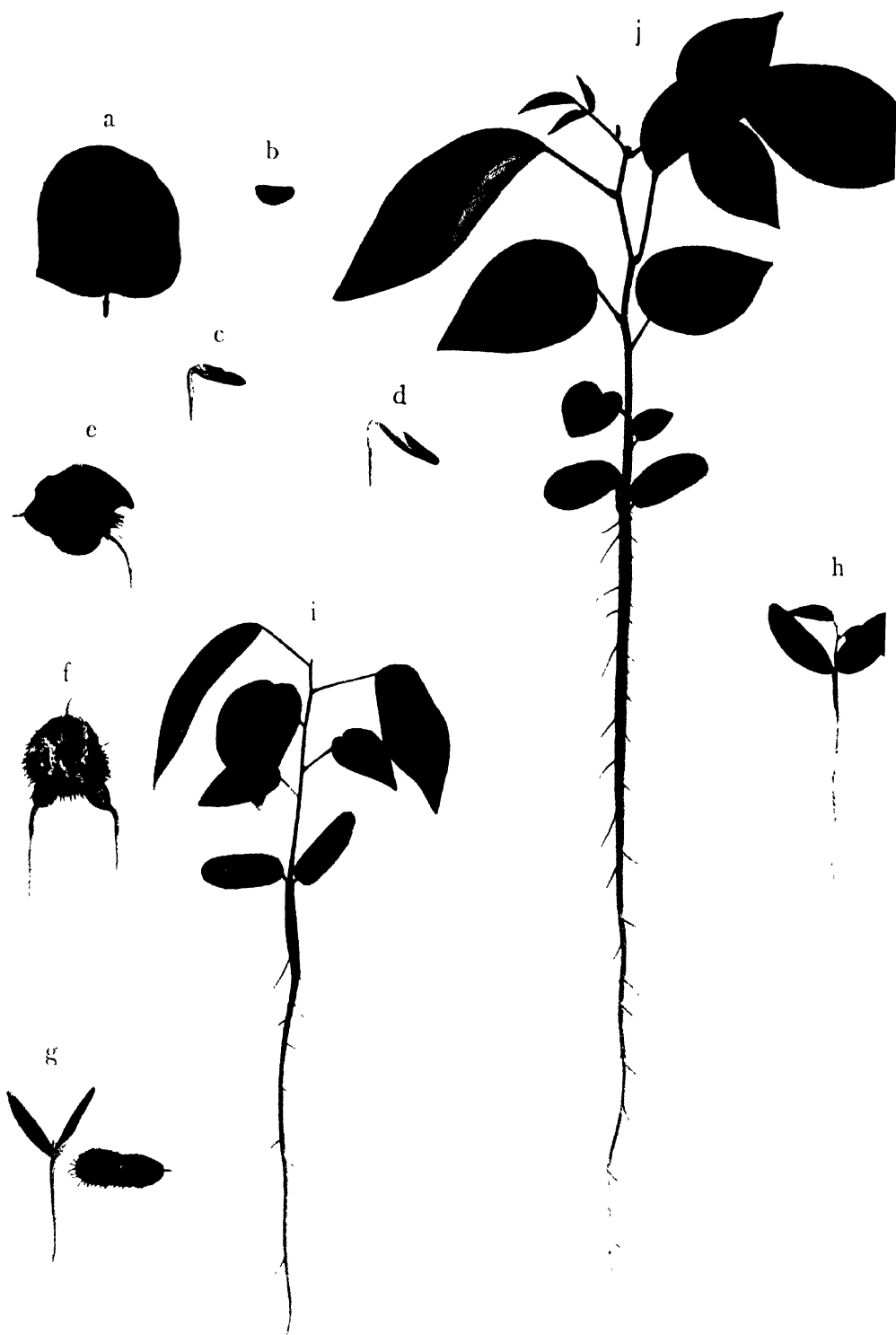


FIG. 108. *Pterocarpus Marsupium*—SEEDLING $\times \frac{1}{2}$

a -Fruit b -Seed c, d—Germination of seed e - g—Germination under natural conditions
h - j Development of seedling to end of first season

woody : lateral roots moderate in number, fibrous : nodules present. *Hypocotyl* distinct from root, 0.3–0.5 in. long, slightly compressed, tapering down, white, soon turning green. *Cotyledons* sub-sessile or shortly petiolate, foliaceous, somewhat fleshy, 0.9–1.1 in. by 0.4–0.5 in., unequally ovate oblong, apex and base rounded, entire, green, glabrous, venation arcuate reticulate ; glands present on the hypocotyl between the cotyledons. *Stem* erect, terete, zigzag at the nodes, green, with minute adpressed hairs. *Leaves* alternate, petiolate, first five or six simple, usually followed by several trifoliate, then 4- or 5-foliate and finally 7-foliate leaves ; 5-foliate leaves begin to be produced in the second season in vigorous plants. *Stipules* 0.15 in. long, linear lanceolate, acuminate. Simple leaves with petiole 0.2–1 in. long, channelled above, with minute adpressed hairs ; lamina 0.6–3 in. by 0.4–2 in., broadly ovate acuminate, mucronate, base obtuse or cordate, entire, glabrous above, pubescent beneath, lateral veins 6–10 pairs ; first two leaves smaller than subsequent leaves. Trifoliate leaves with rachis 1.5–3.5 in. long ; leaflets alternate, with short petiolules up to 0.1 in. long, ovate or elliptical, apex acute or rounded or retuse, mucronate, base rounded, entire, glabrous above, pubescent and paler beneath ; terminal leaflet 2.5–3.5 in. by 1.4–2.5 in., lateral leaflets 1.5–2.8 in. by 1–2 in.

The development of the seedling during the first year is comparatively slow, a height of about 2 to 6 in. being attained by the end of the first season under natural conditions, though in seed-beds regularly watered and weeded a height of as much as 3 ft. or more may be reached. During the second season the growth is faster, a height of about 2 to 5 ft. or more being attained under favourable natural conditions and as much as 5 to 8 ft. or more in the case of plants regularly watered and weeded. A long taproot is produced at an early stage, the taproot sometimes reaching a length of 1 ft. in the first month. Natural forest seedlings may show little stem development or may die back annually for several years, ultimately shooting up after they have developed a long stout taproot. Although the seedlings are capable of struggling successfully against a moderate growth of low weeds and grass their development is greatly stimulated by weeding and loosening of the soil. They are very frost-tender, suffering particularly amongst grass and less so in beds kept weeded and watered. They are also sensitive to drought in their earlier stages, and benefit by side protection from the sun on dry ground. During germination the radicle is very liable to dry up before reaching the soil if the pods are lying on the surface of the ground exposed to the sun, and the seedling almost invariably perishes : under shade and in comparatively moist situations, however, the young root has the power of creeping along the ground for some distance and retaining its vitality until it finds an opportunity of penetrating the soil. This vitality of the young root during and immediately after germination in places not exposed to drought is noticeable in the case of pods falling amongst grass and weeds and suspended an inch or two above ground ; here in moist situations germination takes place and the young root is for a time aerial until it reaches the soil, the cotyledons being capable of providing nourishment in the meantime. The radicles of germinating seedlings are much subject to the attacks of insects, but unless the damage is severe the seedling is capable of surviving. Although germination can take place under dense shade the seedlings will not survive and develop except under comparatively light shade. Young plants are much subject to browsing by cattle, goats, and deer.

SILVICULTURAL CHARACTERS. The tree is a moderate light-demander. Seedlings and saplings are capable of pushing their way through shrubby growth, and saplings and poles can stand a fair amount of lateral shade but will not tolerate any but the slightest overhead shade. Complete freedom overhead is necessary for proper development from the pole stage onwards. Young plants are frost-tender. In the abnormal drought of 1899 and 1900 trees suffered rather severely in the drier parts of the Peninsula. The tree produces root-suckers, as a rule sparingly. It usually coppices fairly well. Experiments carried out in North Chanda in 1909 showed that both in coppicing and in pollarding capacity it was inferior to the teak and far inferior to *Lagerstroemia parviflora*: if anything it was found to pollard better than to coppice. As regards the best season for coppicing, these experiments gave the following percentage of success where the coppicing was done in different consecutive months—April, 100 per cent.; May, no stools; June, 100 per cent.; July, 33 per cent.; August, 0 per cent.; September, 0 per cent. In some localities, particularly in Indian states, the trees have been extensively damaged by lopping for cattle fodder.

NATURAL REPRODUCTION. Under natural conditions germination starts early in the rainy season, and the two most important factors which favour the early development of the seedling are a loose soil clear of weeds in which the pods become wholly or partially buried by the early showers of rain, and shelter from the heat of the sun; for the latter reason seedlings may be found establishing themselves, even in dry exposed places, behind the shelter of rocks, stones, clods of earth, bushes, &c. It has already been mentioned that where the pods are lying on the surface of the ground the radicles of germinating seeds, if exposed to the sun, are liable to dry up; this is a common cause of mortality in dry places and on stiff soils, particularly when a break in the rains occurs in the early part of the monsoon. Where the pods fall among weeds or thick grass germination may, as already stated, take place an inch or two above ground-level, the young root surviving for some time and in some cases reaching the soil; under such conditions, however, the percentage of mortality is high, for the root tends to rot in moist places and to dry up in dry places. Natural reproduction is sometimes good in grassy areas, and in dry places it may be found in the form of thickets under the moderate shade of other trees.

Most of the pods fall in the hot season and are liable to be damaged by fire unless fire-protection is enforced. Grazing is very inimical to successful reproduction, seedlings being practically absent in heavily grazed areas. Small plants which have been repeatedly burnt back or grazed are often found with a thickened root showing several years' growth. Measures possible for stimulating natural reproduction are the exclusion of fire and grazing, hoeing the soil where seed-bearers are present, and gradually freeing the young plants from overhead cover when they become established.

ARTIFICIAL REPRODUCTION. Owing to the hardness of the pods germination is a matter of some difficulty, and the percentage of success is comparatively low. Experiments at Dehra Dun have shown that germination can be hastened to some extent by soaking the pods in water for a few days prior to sowing; it is still further hastened if, before soaking, the ends of the pods are cut across

sufficiently to admit the water into the pod. Germination can also be stimulated by placing alternate layers of pods and dead leaves in a pit, which is then flooded with water : as soon as germination starts the pods are removed and sown in the nursery. The extraction of the seeds is a tedious matter, but they germinate in a few days if extracted and soaked prior to sowing. If the pods are sown without soaking germination ordinarily starts in two to four weeks.

Direct sowing has proved more successful than transplanting from nursery beds. If transplanting with entire roots and stems be carried out this should be done early in the first rains when the seedlings are still small, and even then great care is necessary. Experiments at Dehra Dun in transplanting seedlings both in the first and in the second rains, after pruning the taproot down to about 8 in. and the stem down to near ground-level, met with only partial success. To raise plants in the nursery the pods should be sown about March or April in drills 9 in. apart in well-raised beds with a porous soil of light sandy loam, regular weeding and watering being carried out. The most successful method of transplanting is to raise the seedlings in bamboo baskets and plant them out in the baskets. Direct sowings are best done in lines, as weeding is thereby facilitated. Line sowings with the aid of field crops should afford suitable protection against the sun, clear lines about 2 ft. wide being left, with the crops in the intervening spaces.

Plantations require careful protection in their younger stages from fire and grazing and from damage by deer.

SILVICULTURAL TREATMENT. In existing working plans the tree is as a rule worked either by selection fellings or as standards in coppice-with-standards. In selection fellings sound trees are ordinarily felled when they reach a girth of 6 ft. or a diameter of 2 ft. ; where large dimensions are obtainable, as in Madura, Belgaum, &c., a girth limit of 7 ft. is fixed. Under ordinary conditions its silvicultural treatment would be combined with that of teak, blackwood, and other valuable species, regenerative operations in high forest consisting of the gradual removal of the overwood over established young growth, the opening of the canopy to stimulate new reproduction, with hoeing of the soil if necessary, and the weeding and cleaning of the young crop. Where natural reproduction fails sowing or basket planting would have to be resorted to.

RATE OF GROWTH. Mr. A. Rodger¹ quotes the case of a tree planted at Chaibassa which reached a height of 20 ft. and a girth of 10 in. in ten years ; he also cites the case of a plantation in Central Coimbatore thirty years old which contained about 200 trees in excellent condition up to nearly 7 ft. in girth.

Periodic measurements of ten trees for seven years in the Walayar reserve, Coimbatore, Madras, showed a mean annual girth increment of 1.5 in. for the period : the trees varied from 1 ft. 7 in. to 3 ft. 1 in. in girth at the beginning of the period. This indicates a fairly rapid rate of growth.

Certain working plans give estimates of rate of growth based on ring countings : it is somewhat doubtful, however, to what extent such estimates can be relied on, as the rings are difficult to determine, and indeed the working plan officer of the North Kanara plan, Mr. Pearson, admits the difficulty of

¹ For. Bull. No. 17.

arriving at an accurate estimate. The following figures based on ring-countings may be quoted :

Pterocarpus Marsupium : rate of growth in high forest, North Malabar.

Diameter.	Average age.	
	Begur forests.	Chedleth Range forests.
in.	years.	years.
6	36	33
12	69	62
18	106	92
24	144	124

Pterocarpus Marsupium : rate of growth in high forest, North Kanara.

Age.	Mean diameter.	
	Kalinaddi slopes forest.	Ankola high forest.
years.	in.	in.
10	1.9	1.65
20	3.5	3.41
30	5.4	5.41
40	7.3	7.44
50	9.1	9.27
60	10.7	11.24
70	12.4	12.35
80	13.8	13.88
90	15.4	15.56
100	16.9	17.20
110	18.5	18.57
120	19.9	19.54
130	21.2	19.73
140	22.2	22.12
150	23.3	24.32
160	24.0	26.30
170	25.3	27.20

Measurements made in 1916 in the Saitba coppice coupes, Kolhan, Bihar and Orissa, on poor hilly ground, gave the following results :

Pterocarpus Marsupium : rate of growth of coppice, Saitba.

Age.	Mean height.	Mean girth.	Age.	Mean height.	Mean girth.
years.	ft.	in.	years.	ft.	ft.
2	4.0	2.0	10	18.3	8.7
4	8.6	4.0	12	21.0	10.0
6	12.0	5.7	14	23.3	11.0
8	15.0	7.3			

2. *Pterocarpus santalinus*, Linn. f. Red sanders. Vern. *Lal chandan*, *chandana-maram*, Tam. ; *Yerra chandanam*, Tel.

A small to moderate-sized deciduous tree with an erect bole and a rather dense rounded crown. Leaves 4-7 in. long ; leaflets coriaceous, three, rarely four or five. Prain notes that leaves having more than three leaflets are always the ultimate leaves of their twig. Bark blackish brown, divided into rectangular plates by deep vertical and horizontal cracks, exuding a red juice when cut. Under natural conditions the tree attains a girth of 3 to 5 ft. and a height of 30 to 35 ft., though in plantations on rich ground a height of 50 to 60 ft. would probably be attainable. Wood extremely hard, dark red to almost black



FIG. 109. *Pterocarpus santalinus* forest in South Cuddapah in which felling of badly-shaped stems has been completed, leaving the better trees.



FIG. 110. *Pterocarpus sandalinus* plantation of 1865 at Kodur, South Cuddapah, age 52 years.

formerly used as a dye, now largely used for carving and ornamental work, and much in request for carved house-posts.

DISTRIBUTION AND HABITAT. The red sanders has a very restricted natural range, extending over an area of only about 6,000 square miles in the south-eastern portion of the Indian Peninsula. It is found chiefly in the Cuddapah district, extending a short distance into the adjoining districts of Kurnool, North Arcot, and Nellore, with an outlier in the Kambakkam and Nagalapuram hills of Chingleput; it does not extend into the Anantapur district to the west of Cuddapah. Its principal home is in the Palkonda or Seshachellam hills of Cuddapah and North Arcot.

In its natural state the tree grows typically on dry hilly, often rocky ground, at elevations of 500 to 3,000 ft. above sea-level: it is sometimes found on precipitous hill-sides. It requires perfect drainage, and is found mainly on stony or gravelly soil on formations of gneiss, quartzite, shale, or laterite: the tree grows particularly well on lateritic loam. On the higher hills it occupies chiefly northern and eastern aspects, but on low hills it is found on all aspects. It will not tolerate stiff water-logged soil, but has been planted with success on rich alluvial ground.

For some years prior to the reservation of the more important red sanders tracts the tree had been declared a reserved tree, and thus escaped the destruction meted out to almost all other species in accessible situations through indiscriminate felling or lopping for manure. In 1883 the aspect of the red sanders forests was described as that of a rocky stony country covered with tufts of lemon grass and with poles of red sanders at intervals of a few yards.¹ Since then these tracts have been reserved and the forest growth has improved considerably.

Among the more typical associates of the red sanders are *Pterocarpus Marsupium*, *Chloroxylon Swietenia*, *Terminalia Chebula*, *T. tomentosa*, *Hardwickia binata*, *Albizia Lebbek*, *A. odoratissima*, *Dalbergia latifolia*, *Buchanania latifolia*, *Lagerstroemia parviflora*, *Anogeissus latifolia*, *Acacia Sundra*, *A. leucophloea*, and locally *Shorea Tumbuggaia*.

Mr. T. A. Whitehead² says that in the south of the Cuddapah district in the southern part of the Seshachellam hills the proportion of red sanders is small, usually about 10 per cent., but the size and quality of the trees are superior to those of trees found in other parts of the district, where the percentage is greater, the tree usually forming over 30 per cent. of the stock and in places growing pure.

Fig. 109 shows a typical natural red sanders area in South Cuddapah, in which a thinning has just been carried out, all misshapen stems having been cut back and the better trees left.

In its natural habitat the tree experiences a comparatively dry hot climate. The absolute maximum shade temperature is about 113° to 116° F. or possibly more, the absolute minimum about 45° to 55° F., and the normal rainfall about 35 to 42 in. Rain is received both from the north-east monsoon (October to December) and from the south-west monsoon (May to September): during the hot months February to May there is little or no rain, and the climate is excessively dry.

¹ Ind. Forester, ix (1883), p. 354.
2307.1

² Note on Red Sanders. For. Bull. No. 34, 1917.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The leaves are shed from January to the middle of March, the leaf-fall taking place earlier in dry than in moist localities : the tree is leafless or nearly so for a short time, the new leaves appearing early in April. The short racemes of yellow flowers appear from April to June ; the pods form rapidly, but do not ripen till next February or March. The pods (Fig. 111, *a*) are 1.4–1.8 in. in diameter including the wing, obliquely orbicular, gradually narrowed into a short stalk, brown when ripe : central portion containing the seeds hard and bony. Seeds one or two, 0.4–0.6 in. long, dolabriform, reddish brown, with a smooth leathery testa. About 25 to 40 dry pods weigh 1 oz. The pods fall for the most part during the hot season, chiefly in May. In the Report of the Forest Department for the year ending June 30, 1909, it is stated that trees fourteen or fifteen years old in Napier's Park, Ganjam, seeded twice during the year, and that the seed germinated well on both occasions.

GERMINATION (Fig. 111, *b-g*). Epigeous. The radicle emerges from the side of the pod opposite the stalk. Sometimes—particularly when two seedlings emerge from one pod—the pod is raised above ground, falling with the expansion of the cotyledons : otherwise the cotyledons are extricated by the arching of the hypocotyl, the pod being left on or in the ground. The testa of the seed is always left within the pod.

THE SEEDLING (Fig. 111).

Roots : primary root long, moderately thick, terete, tapering, wiry to woody : lateral roots moderate in number, fibrous, distributed down main root : nodules present. *Hypocotyl* distinct from root, 0.4–1 in. long, slightly compressed, fusiform or tapering up or down, white turning green. *Cotyledons* sub-sessile or with petioles up to 0.06 in. long, foliaceous, somewhat fleshy, 0.8–1 in. by 0.3–0.45 in., unequally ovate oblong, entire, apex rounded, base rounded or sagittate or semi-sagittate. *Stem* erect, wiry, green, pubescent ; internodes 0.3–1 in. long in natural seedlings. *Leaves* alternate, petiolate, normally all simple during first season, subsequent leaves trifoliate. Stipules linear lanceolate or sub-falcate, acuminate, pubescent. Simple leaves with petiole 0.1–0.5 in. long, channelled above, pubescent ; lamina 0.4–1.8 in. by 0.4–1.8 in., cordate, acute rounded or emarginate, mucronate, entire, glabrescent above, pubescent below, venation arched reticulate.

A detailed study of the seedling in its natural home has not yet been made. From numerous specimens received from Cuddapah it would appear that under natural conditions a height of about 4–6 in. is ordinarily attained by the end of the first season, a long taproot being developed. Experiments at Dehra Dun showed that the seedlings are capable of making their way successfully through a moderate growth of grass and weeds, but that weeding and loosening of the soil stimulate their development. As in the case of *P. Marsupium*, when the pods are lying uncovered on the surface of the ground the radicles are apt to dry up during germination if exposed to a hot sun, and are also subject to insect damage ; there is far less mortality where the pods are covered with earth. Frost is unknown in the natural habitat of the tree ; at Dehra Dun seedlings have invariably been killed by frost in the winter. The seedlings, like those of several other Indian trees, in their natural state die back in dry seasons, but the root-system is unaffected and new shoots are subsequently produced ; this dying back may be repeated annually for a series of years until the plants are strong enough to produce permanent shoots.

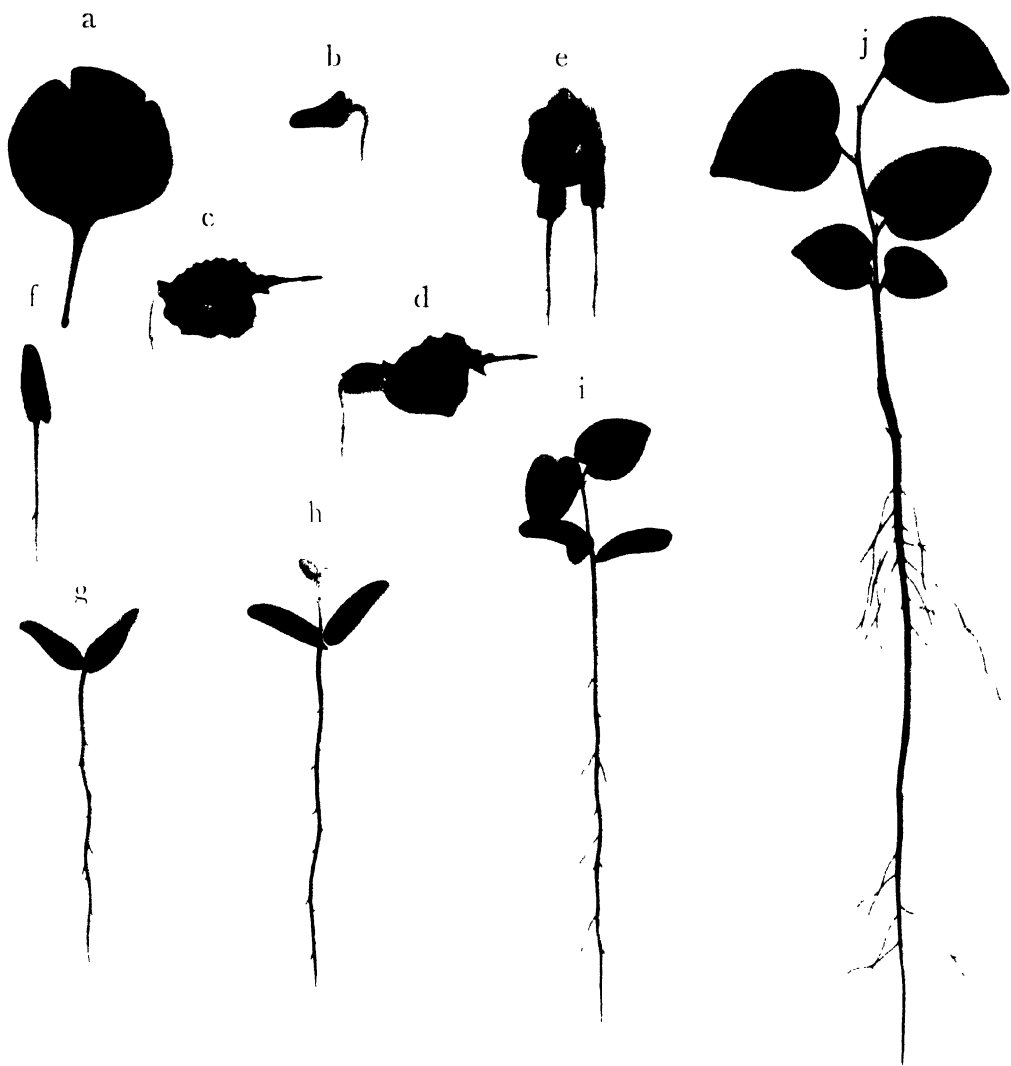


FIG. III. *Pterocarpus santalinus*—SEEDLING $\times \frac{1}{2}$

a—Fruit b—Germinating seed c - g - Germination stages under natural conditions
h - j—Development of seedling to end of first season

SILVICULTURAL CHARACTERS. The red sanders is a light-demander, and will not tolerate overhead shade. Experience gained in the Kodur plantation, described below, shows that an abundance of growing space and room for crown development is necessary for the proper growth of the tree ; in other words, regular thinnings are required to promote the best growth. It is not exacting as regards soil, being often found on poor dry shallow soil, though naturally it shows better growth on rich soil ; perfect drainage, however, is essential. It coppices vigorously and produces root-suckers freely. It resists fire well, even seedlings escaping serious damage better than most species. Young plants are readily browsed by cattle and deer.

NATURAL REPRODUCTION. The conditions favouring natural reproduction require further study, but so far as experiments at Dehra Dun go the ideal conditions would appear to be similar to those which favour the reproduction of *P. Marsupium*, namely, a loose soil, in which the pods become wholly or partially buried, and shelter from the heat of the sun in the germinating and seedling stages. Under natural conditions germination takes place in the early part of the south-west monsoon, and as a rule the seed germinates readily and natural reproduction is easily obtained in areas protected from fire and grazing ; the young plants benefit by protection from the sun in hot places.

ARTIFICIAL REPRODUCTION. So far little experience has been gained in raising plantations by direct sowings. Such experiments as have been made show that there is considerable risk of mortality by drought in the early stages, and it is possible that the system of sowing along narrow cleared lines with field crops in the intervening spaces may prove successful, the crops affording the necessary side shelter : this system is described under *Dalbergia Sissoo*.

The method of basket planting has so far proved the most successful, and appears to have been the one most generally employed in the case of the small plantations which have been made in different localities from time to time. The method, as described by Mr. H. H. Yarde,¹ is to raise seedlings in seed-beds and to transplant them when about one year old into bamboo baskets 1 ft. deep and 9½ in. in diameter : great care is necessary to lift the seedlings with earth round the roots and without damaging the taproot, this being done with the aid of a long-bladed pointed iron instrument known as a *tunkar*. The baskets are placed under shade and watered regularly every second or third day, and the basketed plants are then put out in prepared pits in the rains, preferably in July. Regular weeding is necessary, as well as watering in dry weather for the first few years. In the early stages it is advisable to shelter the young plants from the sun in hot weather ; this has been done by fixing leafy branches round each plant and tying them at the top ; Peruvian cotton grown in the plantation has also been found to give effective shelter. According to Mr. Yarde a distance of 12 to 15 ft. between plants has been found to give the best results.

The best known red sanders plantation is that at Kodur in the Pullampet valley, Cuddapah district, formed in 1865 by the system of basket planting just described. This plantation, which is situated on rich alluvial soil, was originally 20 acres in area, but has been extended subsequently ; in 1912 the

¹ Ind. Forester, ix (1883), p. 137.

area of well-established red sanders of the original plantation was estimated to be 15 acres. The history of this plantation shows very forcibly the need for regular thinnings ; in the earlier years the plantation was carefully tended and the growth was rapid, an average annual girth increment of about 1 in. having been recorded during the first eighteen years ; subsequently, however, thinnings were neglected, and the average annual girth increment fell to considerably less than half this rate, the dominated trees showing an average total increase of not more than 1 in. for the twenty-nine years 1883 to 1912. The density of the plantation in 1912 can be imagined from the fact that in a sample area in which periodic measurements had been made there were no fewer than 270 trees per acre, a density far too great for a species so intolerant of crown suppression. Fig. 110 shows a portion of this plantation in 1917, when fifty-two years old.

The tree grows to some extent from cuttings, provided these are kept well watered.

SILVICULTURAL TREATMENT. In the natural forests the most suitable silvicultural treatment is suggested by the readiness with which natural reproduction springs up in areas protected from fire and grazing and establishes itself if sufficient light is afforded. This would indicate that the most satisfactory method of regenerating the forests would be to protect them carefully and to confine regenerative operations to definite periodic blocks, freeing all existing young growth, thinning pole and sapling crops, opening the canopy to stimulate further reproduction, and carrying out works of artificial reproduction where required ; in blocks not under regeneration thinnings in favour of red sanders and other valuable species, together with the removal of mature or deteriorating stock, would be necessary. It is not yet certain what would be the most suitable rotation or regeneration period to adopt, but judging from existing records of rate of growth, it is probable that in regularly tended crops under forest conditions a rotation of about sixty years will suffice, and this might be conveniently divided into three or four regeneration periods of fifteen or twenty years each.

Owing to the partially ruined condition of the red sanders forests the system provisionally adopted hitherto has been that of thinnings (improvement fellings) combined with strict protection, extraction being confined to dead, unsound, and misshapen trees (see Fig. 109).

RATE OF GROWTH. Statistics regarding the rate of growth are at present somewhat fragmentary. As already stated, the Kodur plantation of 1865, on rich alluvial ground, showed an average annual girth increment during the first eighteen years of about 1 in. ; during the following twenty-nine years, in consequence of overcrowding, the maximum rate of growth was only 0.65 in. per annum. In 1881, the plantation being then sixteen years old, Dr. Brandis estimated that it had a volume of 2,400 cub. ft. per acre and was producing an annual volume increment of 150 cub. ft. per acre. In 1883 (age eighteen years) the trees in this plantation had a mean height of 40 ft. and a mean and maximum girth of 18 in. and 30 in. respectively.¹ In 1915, when the plantation was fifty years old, the largest tree in it had a girth of 52 in. A sample plot measured in 1917 had 218 stems with an estimated volume of

¹ Ind. Forester, ix (1883), p. 357.

1,710 cub. ft. per acre (see Fig. 110). Mr. P. M. Lushington records that in a plantation in Chittoor, believed to have been formed not later than 1863, the largest tree measured by him in 1912-13, the plantation being then at least fifty years old, had a girth of 48 in., and there were other trees nearly as large.

In natural forest the mean annual girth increment is usually considered to vary from 0.5 to 0.75 in. Mr. Whitehead¹ says a seedling tree commences to form heartwood at the age of about eighteen years, when it has attained a girth of 6-9 in. at breast height, while a coppice-shoot shows signs of forming heartwood at an age of fifteen years, when it has attained a girth of 9-15 in. A premature deposit of the red colouring principle santalin is often found round injured parts. He says a tree seventy to eighty years old, which as a rule averages 40-50 in. in girth at breast height, may be said to have attained exploitable age, that is, the age at which it is capable of yielding a special house-post.

3. *Pterocarpus dalbergioides*, Roxb. Andaman redwood, Andaman padauk. (This is the correct Hunterian spelling of the word, which is often wrongly spelt 'padouk'. The pronunciation of the diphthong *au* is as in 'how' or 'now': the first syllable is short.) Vern. *Padauk*, Burm. (in Andamans); *Chalanga-da, da*, And. (Fig. 112.)

A very large semi-deciduous or practically evergreen tree with ascending branches, attaining a height of 80-125 ft. with a clear bole of 20-50 ft. and exceptionally up to 60-80 ft., and a girth sometimes reaching 18 ft. Leaves 8-10 in. long with five to nine leaflets. The bole is often much buttressed at the base, particularly on low-lying ground and on shallow dry soil, while large over-mature trees are usually unsound. Many of the older padauk trees, which have evidently grown up in a fairly open situation, are crooked in the bole and branch low down.

The wood is moderately hard, the colour of the heartwood varying from light greyish brown to bright red or a rich reddish brown streaked with darker markings: the paler coloured wood is known on the market as 'off colour' padauk, and has a lower market value than the red wood. Whether or not these variations in colour, which are of much economic importance, are due to any external conditions has not yet been determined; they are not accompanied by any variation in botanical characters.

The padauk is the principal timber tree of the Andamans, the red wood being highly esteemed for furniture, railway carriages, billiard tables, panelling, and interior building or decorative work generally: it has gained a footing on the European and American markets, and is in considerable demand. The wood of the buttresses is usually of excellent colour and beautifully figured: one such buttress yielded an oval table 12 ft. 9 in. long by 7 ft. broad, which was in the possession of the late Lord Kitchener.

This is not the true padauk tree, which is *P. macrocarpus*, Kurz, the Burma padauk; the Andaman tree received its name from Burmese convicts owing to its generic similarity to the tree they knew in their own country.

DISTRIBUTION AND HABITAT. Throughout the Andaman Islands. Very scarce in Great Coco, just north of North Andaman (Prain). Not known in

¹ *loc. cit.*

the Nicobar Islands, Narcondam, or Barren Island. The total area of the Andaman Islands being under 2,000 square miles, it has a more restricted distribution than any other Indian tree of the same importance. It has been cultivated to a small extent in Bengal, southern India, and Burma.

The tree is not gregarious, but is found scattered in mixed deciduous or semi-evergreen forests from near sea-level up to about 300 ft. elevation, growing best on the well-drained lower slopes of the hills and in the broader valleys, where it is often found along the tidal creeks just above the mangrove belt, which may be only a few yards wide or may extend to a width of a mile or more. Above the padauk belt, and covering the upper slopes and tops of the hills, dense evergreen forest occurs. In the portions of the South Andaman and other islands explored by Mr. Rogers padauk forest was estimated to occupy only about 30 per cent. of the total forest area, while in the North Andaman Mr. Todd estimated that some 48 per cent. of the area was occupied by padauk forest, the remainder consisting of evergreen forest and mangrove swamps.

As regards the factors determining the local distribution of the padauk and evergreen forest, Mr. F. H. Todd ¹ notes regarding the North Andaman that the underlying rock does not exercise any influence, since it shows little variation throughout the island, consisting as it does of sandstone and conglomerate with intrusive rock, chiefly serpentine in one locality; nor can the depth of soil have much influence, since although padauk does occur on flat ground with deep soil, the finest trees are invariably found on well-drained sheltered slopes, and it will grow on hill-sides even where the soil is very shallow. Altitude, again, need hardly be considered, since the difference in temperature at sea-level and 300 ft. is practically imperceptible. It is probable that the existence of padauk, at all events in the North Andaman, is dependent on the degree of shelter afforded to it, that is, on aspect and situation. Thus it is usual to find on all areas along the coast which are exposed to the south-west monsoon a covering of dense evergreen forest unproductive of padauk, and a short distance behind this protective evergreen belt rich padauk-bearing forest is often found. In sheltered valleys, again, padauk grows at a higher altitude than in exposed situations, where padauk is rarely found at all. Among other specific examples Mr. Todd quotes the case of the country lying between the main watershed and the west coast of the North Andaman Island, which is on the whole flat, with the exception of occasional isolated knolls and ridges rising 200 to 300 ft. above the surrounding country: on the flat ground padauk forest is found, but on the exposed knolls and ridges, although the underlying rock is the same, nothing but evergreen forest unproductive of padauk occurs.

As regards the South and Middle Andaman and other islands, where the geological formation varies from place to place, Mr. Rogers ² notes that the underlying rock exercises a decided influence on the relative distribution of the padauk-bearing and the evergreen forest. Thus the semi-deciduous padauk forest is never found where the underlying rock is the grey, usually soft, non-

¹ Draft Working Plan for the Forests of the North Andaman, 1906; also Ind. Forester, xxxii (1906), p. 581.

² Report on the Exploration of the Forests of the South Andamans and other Islands, 1906, paras. 20 and 21.



FIG. 113. *Pterocarpus dalbergioides* in semi-evergreen forest, Andamans.

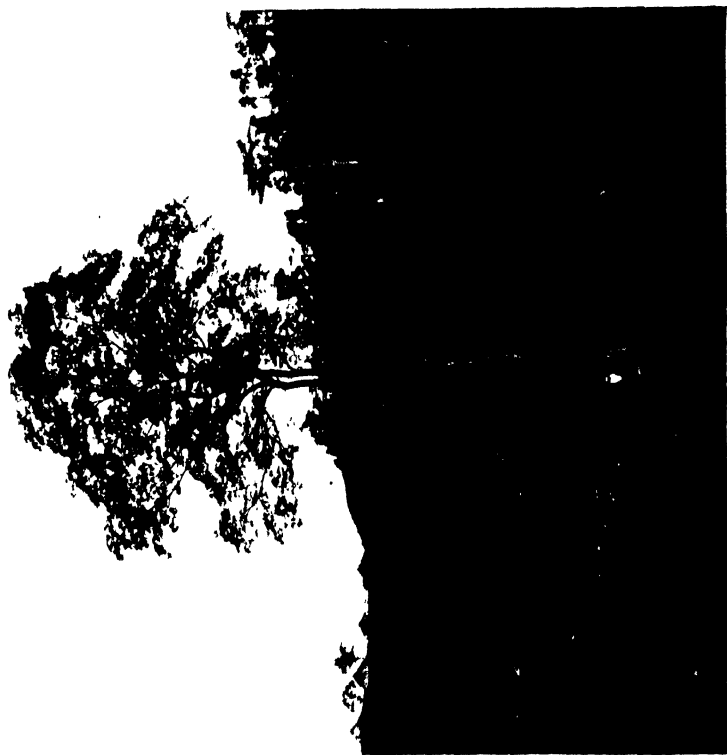


FIG. 112. *Pterocarpus dalbergioides*, Andamans.

calcareous micaceous sandstone of the Port Blair series; this geological formation supports evergreen forest. The padauk-bearing forest is, with certain exceptions, always associated with the series of rocks termed the Baratang beds, which are often metamorphosed and consist typically of indurated clays and shales, conglomerate, blocks of quartzite, crystalline limestone, and hard coarse-grained non-micaceous sandstone. Again, in the padauk-bearing forest itself the associate species themselves depend to some extent on the nature of the soil: where patches of sandy soil occur evergreen species are found, and as the proportion of clay increases these give way to deciduous trees.

The padauk is associated with various other species of trees, some deciduous and some evergreen, the more important of which are *Lagerstroemia hypoleuca* (chiefly on low ground, rarely on hills), *Terminalia bialata*, *T. Catappa* (on sandy soil and often near the sea-shore), *T. Mannii*, *Albizia Lebbek*, *Bombax insigne* (chiefly on lower slopes), *Sterculia* spp., *Careya arborea*, *Odina Wodier*, *Artocarpus Chaplasha* (chiefly on the hills), *A. Lakoocha*, *Adenanthera pavonina* (on sandy soil and often near the sea-shore), *Diospyros Kurzii* (on the hills), *Planchonia andamanica*, and *Mimusops Elengi*. Two more or less distinct types of padauk-bearing forest are distinguishable; these may be termed the deciduous and the semi-evergreen types. The former, which is perhaps more typically represented in the North Andaman, is characteristic of hot southern aspects, and the trees are largely if not entirely deciduous: the semi-evergreen type, which occurs on cool northerly aspects and in damp localities, includes besides deciduous trees certain evergreen species characteristic of the evergreen forests, such as *Dipterocarpus* spp., *Hopea odorata*, *Mesua ferrea*, and others.

In the deciduous forests the undergrowth consists mainly of young tree species, thorny creepers, and occasional shrubs. In the semi-evergreen forests the undergrowth is denser, consisting partly of canes (*Calamus andamanicus* and *C. pseudo-rivalis*) and scandent bamboo (*Dinochloa andamanica*) with pure bamboo forest (*Oxytenanthera nigrociliata*) in parts. Fig. 113 shows a padauk tree in semi-evergreen forest.

Mr. Rogers¹ describes a special type of padauk-bearing forest on diluvial deposits formed by the detritus brought down by streams when in flood; these deposits, consisting of deep sandy soil, are often found behind the mangrove swamps and between them and the hills beyond. The forest on these deposits partakes of the characters both of the padauk-bearing and of the evergreen types. Near the mangrove swamps and within the influence of the high spring tides the growth consists of *Phoenix paludosa*, *Licuala peltata* and *L. spinosa*, *Heritiera littoralis*, *Areca triandra*, and *Cynometra ramiflora*. Beyond the influence of the tide padauk occurs along with several of its common associates, the forest trees standing over a dense tangled growth of canes, creepers, climbing bamboos, and two species of *Daemonorops* (*D. Kurzianus* and *D. Mannii*) along with various canes of the evergreen forest, such as *Calamus andamanicus*, *C. tigrinus*, *C. palustris*, *C. gracilis*, and others. The presence of padauk in this type of forest does not necessarily imply its presence in the hills beyond, which may be covered with evergreen forest; in this case

¹ *loc. cit.*, para. 26.

Mr. Rogers considers it probable that the padauk seed was originally brought on to the area by the tides.

In the padauk-bearing forest padauk is as a general rule the predominating species, but the canopy is usually open, and the number of trees per acre is not great. Mr. Todd's enumerations in the North Andaman showed an average of 202 sound padauk trees over 3 ft. in girth per 100 acres. From Mr. Rogers's enumerations in the South Andaman and other islands the average number of sound trees of all species 6 ft. in girth and over was estimated to be 197 per 100 acres, of which padauk numbered 93 and its associates 104 trees per 100 acres: including sound and unsound trees the estimate showed an average of 135 padauk trees 6 ft. in girth and over per 100 acres.

More recent enumerations by Mr. Bonig, combined with Mr. Todd's figures for the North Andaman, have yielded the following estimate of padauk trees existing in 1914: ¹

Pterocarpus dalbergioides: estimate of trees in the Andamans forests in 1914.

Locality.	Area of padauk-yielding forest. acres.	Estimated number of padauk trees in girth class.							
		Unsound.	Sound.						
		7½ ft. and over.	9 ft. and over.	7½-9 ft.	6-7½ ft.	4½-6 ft.	3-4½ ft.	1½-3 ft.	
North Andaman felling series .	98,464	35,171	21,414	21,571	39,756	32,572	23,366	29,872	
Middle Andaman felling series .	108,625	68,947	45,901	43,718	46,107	39,063	24,112	18,458	
South Andaman felling series .	71,823	71,368	8,298	6,726	10,791	17,019	16,891	20,627	
Total .	278,912	175,486	75,613	72,015	96,654	88,654	64,369	68,957	
Estimate per 100 acres .		63	27	26	35	32	23	25	

A noticeable feature of the padauk forests is the preponderance of mature and over-mature padauk trees, the younger age-classes being inadequately represented or in some cases entirely absent. Seedlings may often be found under seed-bearers during the rains, but except where the cover is very light they disappear before next year owing to suppression, and it is only in places where clearings have admitted light that established saplings and young poles are to be found in any quantity. Mr. B. B. Osmaston ² notes that this remarkable disparity in the age-classes can be explained only by assuming that there has been a recent change in the condition of the vegetation in the Andamans, the conditions under which the existing crop of mature and over-mature trees arose having given place to others unsuitable to the successful reproduction of the padauk: this change possibly consists in an increase of moisture favouring shade-enduring species to the detriment of padauk. Whatever the precise causes may be, the fact remains that the young crop of padauk is hopelessly inadequate to take the place of that which is now ripe for removal.

As regards the climatic conditions under which the padauk grows in its natural habitat, the absolute maximum and minimum temperatures at Port Blair are 99° and 60° F. respectively, and the normal rainfall is 118 in. At

¹ Working Plan Report of the Andamans Forest Division, 1916.

² Ind. For. Records, vol. i, pt. iii.



FIG. 114. *Pterocarpus dalbergioides* —SEEDLING $\times \frac{1}{2}$

a - Fruit b—Seed c, d Germinating seed e-h Germination stages under natural conditions
i-k. -Development of seedling during first season

Wimberleyganj, five miles distant, the rainfall is 169 in. : in the North Andaman Island it is probably somewhat less than at Port Blair, since the forests are of a drier type than in the south of the group. The great bulk of the rain falls during the south-west monsoon from May to October : a fair amount falls during November, December, and April, but little or none from January to March. The climate is damp for the greater part of the year.

FLOWERING AND FRUITING. The yellow flowers in large panicles, which are terminal, or axillary only towards the ends of the branches, appear in the rainy season about June. The pods (Fig. 114, *a*) commence forming rapidly, and ripen the following January to March : when ripe they are dark reddish brown, 1.8–2.2 in. in diameter including the wing, orbicular, tapering down to the stalk, one- or two-seeded, the central portion, containing the seeds, hard and bony : about 550 to 600 pods weigh 1 lb. Seeds (Fig. 114, *b*) 0.4–0.5 in. long, dolabriform, flattened, reddish brown, smooth, shiny, testa fairly thin and brittle. The tree seeds abundantly almost every year. The immature pods are destroyed in large quantities by parakeets during the cold weather months. Most of the ripe pods remain on the tree during the months of March, April, and May.

Tests carried out in the Andamans have shown that the seed retains its fertility unimpaired for at least two years if stored in a dry place. So far as experience goes, however, the percentage of fertility is not as a rule high. Tests carried out at Dehra Dun and in the Andamans in 1911 showed a fertility of 50 and 60 per cent. respectively : in the latter case the seed had been stored for a year. Seed sown in plantations in different parts of Burma showed percentages of success amounting to 16, 20, and 23, while in the Andamans in 1911, even when five pods were sown at each stake, the percentage of success amounted to only 68 : in plantations, however, the percentage of success would naturally be lower than the percentage of fertility as ascertained by careful tests, though for practical purposes it is probably of more value.

GERMINATION (Fig. 114, *c–h*). Epigeous, resembling that of other species of *Pterocarpus*. Two fertile seeds are rarely contained in one pod, so that as a rule only one seedling emerges. The radicle issues from the side of the pod opposite the stalk, and bends downwards into the ground. The pod either is left on or in the ground, the cotyledons extricating themselves by the arching of the hypocotyl, or is carried up above ground, falling with the expansion of the cotyledons. The testa remains inside the pod.

THE SEEDLING (Fig. 114). Description of plants grown under natural conditions.

Roots : primary root moderately long, terete, tapering, wiry to woody : lateral roots numerous, fibrous, distributed down main root : nodules present. **Hypocotyl** distinct from root, 1.2–2 in. long, compressed, fusiform or tapering upwards, green, minutely pubescent. **Cotyledons** sub-sessile, foliaceous, somewhat fleshy, 0.8–1.2 in. by 0.3–0.4 in., unequally ovate oblong, apex rounded, base semi-truncate, entire, green, glabrous ; glands present on the hypocotyl between the cotyledons. **Stem** erect, terete, tomentose ; internodes in first season 0.2–0.8 in. long. **Leaves** alternate, petiolate, first few simple, followed usually by a few trifoliate leaves, then by 4-foliate leaves, after which the number of leaflets increases ; sometimes no compound leaves are formed until the second season. **Stipules** 0.1 in. long or less, linear falcate, pubescent.

Simple leaves with petiole 0.2-0.5 in. long, channelled above, pubescent; lamina 0.6-2.5 in. by 0.5-1.5 in., ovate or cordate acuminate, slightly mucronate, entire, glabrescent above, pubescent beneath; early leaves small, successive leaves increasing in size.

In the Andamans the germination of the seed takes place during the rainy season, for the most part up to the end of July, and under favourable conditions the development of the seedling is rapid. In *tarungya* plantations, where the forest growth is cleared and burnt prior to the sowing of the seed and the seedlings are regularly weeded, a height of as much as 5 ft. or even more may be attained by the end of the first season, whereas under natural conditions where insufficient light is admitted and weeding is not carried out a height of not more than a few inches may be attained in the same time, though in openings where there is abundance of light natural seedlings may, like those in plantations, attain a height of 5 ft. or more. Suppression by dense low cover is fatal to the seedlings: and although they will persist under the moderate shade of high tree cover, abundant light is necessary for their best development. If regular weeding be carried out a height of several feet is attained by the end of the second season: in a *tarungya* plantation of 1911, on padauk-bearing land in the South Andaman, a height of 8 to 10 ft. was recorded one year from date of sowing, that is, in the middle of the second season.

Experiments carried out at Dehra Dun have shown that in the case of pods lying above ground the radicle of the germinating seed, as in the case of other species of *Pterocarpus*, is very liable to dry up if exposed to a hot sun; it suffers also from the attacks of insects and birds. If the pods are buried there is much less mortality during the germinating stages. In the Andamans the seedlings suffer much from cattle grazing in areas where cattle are admitted: in plantations in Burma young plants have been found to be very subject to the attacks of deer, which, however, are not found wild in the Andamans. Crickets have also been the cause of much mortality among seedlings in the Burma plantations.

In its natural home the young plant suffers much from the attacks of defoliators during the first few years of its life, the leaves often being entirely stripped off. Perhaps the worst enemy of the young sapling, however, is the padauk weevil, which causes immense damage, particularly in plantations. This insect is prevalent during the rainy season, its mode of attack being to ring all the young tender shoots as soon as they are produced; these shoots die off and are replaced by new ones, which are in turn ringed and killed off until the young plant assumes a bush-like form. The more vigorous plants eventually survive and produce leading shoots, but the weakly ones succumb. After the first few years the saplings which survive are less subject to this form of damage, and eventually escape it altogether. It has been noticed that young natural plants growing close together are less subject to the attacks of the padauk weevil than more isolated plants.

Frost is unknown in the natural habitat of the tree, and, as might be supposed, the seedlings are extremely frost-tender if grown in localities subject to frost. Seedlings raised at Dehra Dun invariably died back during the winter, and never recovered.

SILVICULTURAL CHARACTERS. Although seedlings will stand a fair amount

of shade from high cover, the tree is a light-demander, and the more overhead light it receives the better is its development.

The padauk grows best on well-drained low undulating ground, where it attains large dimensions ; on flat ground, where the drainage is not so good, although it may reach a considerable size it tends to form large buttresses and is often unsound. Although the trees are not so numerous in the semi-evergreen as in the deciduous type of forest they attain larger dimensions in the former ; in the latter type, although the trees are numerous they are more stunted.

The tree coppices well, and Mr. Osmaston remarks that this power is retained to a great age, since quite old trees on being felled frequently send up strong shoots.

NATURAL REPRODUCTION. The unsatisfactory state of the natural reproduction of padauk in the Andamans has been the subject of frequent comment on the part of officers who have inspected the forests of those islands, and the unanimous opinion recorded is that natural reproduction throughout the great bulk of the forests is almost entirely absent.

Under natural conditions germination may take place as early as April, and it continues for some time into the rainy season, when numerous seedlings may be found ; these, however, disappear before the following year owing to suppression by the dense undergrowth. Only in the drier and poorer types of forest, where the undergrowth is scanty, do seedlings appear to be able to survive to some extent. In the North Andaman, where the type of forest is somewhat drier than elsewhere, Mr. Todd¹ remarks that, except where there is a dense undergrowth, padauk saplings may be found in fair quantity, the overhead canopy being open ; he notes that the seedlings appear capable of standing a considerable amount of shade as long as the canopy causing the shade is at some height from the ground, and instances the case of padauk saplings growing vigorously in bamboo forest where there is usually little or no undergrowth, in spite of the heavy canopy 20-30 ft. above them.

Omitting those parts of the North Andaman where the undergrowth is scanty or absent, however, it may be said that the natural reproduction of padauk is under ordinary conditions absent for all practical purposes. It was at one time thought that this failure was due to a large extent to infertility of seed or to its destruction by parrots, but this theory has been exploded for some time, since there is often no lack of young seedlings in the neighbourhood of seed-bearers, though they cannot survive many months owing to suppression, while the parrots do not consume excessive quantities of seed. On the other hand, natural seedlings appear freely where sufficient light is admitted to the soil, and plentiful natural reproduction has repeatedly been observed in areas where heavy fellings have taken place, on land cleared for plantations, along dragging paths, along the tramway-line clearing, and in similar openings in the canopy. It has been found by experience, however, that even in places where seedlings appear in quantity owing to the admission of light they are doomed to extinction unless kept free by means of cleanings from the masses of creepers and soft woods which grow up with them and would otherwise quickly suppress them.

¹ Ind. Forester, xxxii (1906), p. 583.

The amount of light required and the nature of the operations necessary to ensure the establishment of natural reproduction have been the subject of some discussion in the past, it being held on the one hand that so long as low cover is removed it is advisable not to make too drastic an opening in the upper canopy owing to the danger of stimulating weeds and climbers, and, on the other hand, that the padauk seedlings and saplings cannot have too much light, and that the admission of sun to the ground has a most beneficial effect. Recent experiments, involving the opening of the canopy and the removal of cover in different degrees of intensity, have indicated that the latter view is the more correct one, and that the more light admitted the better will be the development of the young crop.

To sum up, it has now been sufficiently well proved that good natural reproduction can be secured wherever seed-bearers are present by opening out the overwood heavily, removing the underwood completely, and carrying out thorough cleanings as often as is necessary until the young crop of padauk is established. It is believed that in the majority of cases annual cleanings for three or four years, with subsequent cleanings at less frequent intervals, will suffice.

Mr. Cavendish has observed that in areas which have been worked over the best natural reproduction occurs in openings caused by fellings made at the time the padauk seed is ripe on the tree, that is, from March to May, and that very little reproduction takes place when fellings are made at other times of the year : he therefore advocates felling only in these three months.¹

ARTIFICIAL REPRODUCTION. The first regular plantations of padauk in the Andamans were made between the years 1883 and 1889. No further plantations were made until 1903, since when fairly extensive areas have been planted up from time to time. Where these plantations have been formed on typical padauk-bearing land and have been properly tended they have proved successful, but in some cases they have been formed on the non-calcareous micaceous sandstones of the Port Blair series on ground naturally occupied by evergreen forest, and here the growth has not been good.

In the case of regular plantations the system commonly adopted has been to clear and burn the natural forest, sow the pods at regularly spaced intervals, and carry out subsequent weedings and cleanings as often as necessary. Experience has shown that an essential condition for success is the complete and early burning of the natural forest in order, first, to diminish the heavy growth of weeds and climbers which spring up after the burning, and which is intensified if the burning is incomplete ; and second, to allow of the padauk seed being sown before the early showers preceding the monsoon in order to induce early germination. For this purpose it is advisable to clear the forest early enough to allow of thorough burning before the end of March and the sowing of the seed in April before the early showers.

Various spacings have been tried, but a spacing of 6 ft. by 6 ft. has been found more satisfactory than spacings of 12 ft. by 3 ft. or 10 ft. by 4 ft., as a heavy growth of grass is apt to spring up between widely spaced lines. Usually two pods have been sown at each stake, but in order to ensure more complete success the number was subsequently increased to five, about 20 lb.

¹ Forest Administration Report for the Andamans, 1916-17.

of pods being required for one acre. Temporary nurseries are formed in the plantations for the purpose of supplying failures by transplants during the first rains. The question of spacing has not yet been satisfactorily settled, for although with a spacing of 6 ft. by 6 ft. the crowns of the saplings commence to form a complete canopy in five to seven years, this spacing has been found to be too wide to prevent low branching and to produce clean straight boles. It has recently been suggested that broadcast sowing would give better results, and experiments carried out so far indicate that this method may prove to be a better one than that of regular spacing, though further experience is desirable in this direction.

After the formation of the plantation its success depends almost entirely on efficient tending. During the first two years regular weedings and cleanings are necessary as a rule about once in two months from April to December, in order to free the padauk from the heavy growth of weeds and climbers which springs up; in the third and fourth years cleanings at longer intervals are necessary. As a rule from the fifth year onwards little is required except occasional thinning and climber cutting. The thinnings should be light and fairly frequent, and should be confined to dominant stems, exposed edges of plantations being left unthinned in order to provide wind-belts. In the early weedings and cleanings care is necessary not to root up the seedlings of soft-wooded species, but merely to cut them back or lop them sufficiently to free the heads of the young padauk, for if the latter are completely freed they tend to branch low down and also to show poor development in the presence of a rank growth of grass which usually springs up when the soil is exposed. The plantation clearings in the Andamans are often covered at an early stage with a prolific growth of natural seedlings of *Trema amboinensis* (closely allied to *T. orientalis* and perhaps not specifically distinct), which perform a useful function in sheltering the ground and drawing up the young padauk; these require cutting and lopping where necessary, but should not be uprooted.

For some years field crops were raised along with the padauk during the first year of the plantation, in order to keep down the weed-growth and to recoup the cost of formation. The only satisfactory crop was found to be the Burma hill paddy, which was sown early in June, a month or more after the padauk: it was found advisable to sow the paddy between the lines of padauk, leaving clear strips along the lines sufficiently wide to prevent the suppression of the seedlings. These plantations with the aid of field crops have not proved to be as successful as was anticipated, for in order to obtain good crops of paddy it was found necessary to clear the weed-growth more drastically than was good for the padauk; latterly therefore the system of raising field crops in the plantations has been abandoned.

The question of forming mixed plantations of padauk and other species of trees, with the view of imitating natural conditions, has been considered. Some of the earlier plantations in the Andamans consisted of an evenly spaced mixture of teak and padauk, but such a mixture has proved unsuitable, since the teak grows more rapidly than the padauk and soon outstrips and suppresses it. A mixture of padauk and pyinma (*Lagerstroemia hypoleuca*) was tried in 1904, and in its earlier stages the plantation showed great promise; later, however, it was found necessary to cut out the pyinma, as it was

commencing to suppress the padauk. The question has recently been raised as to whether it would not be preferable to employ the available labour in the Andamans in forming plantations of teak rather than of padauk. The former is not indigenous in the islands, but has been introduced and grows remarkably well: there can be no doubt that with its more rapid growth and greater volume production as compared with the padauk it would prove a more remunerative species.

Apart from regular plantations, cultural operations have been tried from time to time in the Andamans. Of these one of the most promising was carried out in 1912 over 40 acres in a forest worked many years previously, in which only hollow trees remained. The undergrowth was cleared, and where the seedlings were numerous under the hollow padauk trees they were transplanted to other parts of the area. This experiment proved very successful where the cover was subsequently kept down.

Attempts to form plantations of Andaman padauk have been made in various parts of Burma. It has been proved that plants can be raised with tolerable success in suitable localities, but on the whole the experiments have resulted in failure. It was found necessary to raise the plants in nurseries and transplant them during the rains. The young seedlings were found to be very subject to the attacks of crickets, while in the plantations deer did much damage by browsing and by nibbling the bark. Seedlings have recently been raised with success in Coorg, but it is too early to say if the introduction of the padauk into that province will meet with success.

In the Andamans plantations the chief danger to be feared is the padauk weevil, which has already been referred to. Fortunately the damage done by this insect, though serious while it lasts, appears to be confined to young plantations, and the trees eventually outgrow the injury.

SILVICULTURAL TREATMENT. The padauk forests of the Andamans have hitherto been worked under selection fellings. This method of working is the only one at present possible where the area to be dealt with is so large and labour is limited. At the same time it will be realized from what has been said above under 'natural reproduction' that the forests cannot be successfully regenerated by this method of treatment, and the only course open seems to be to set aside a suitable area to be regenerated during a period of years, with the idea of regenerating further areas in subsequent periods. The regenerative operations would consist of opening the canopy, clearing the undergrowth where seed-bearers are present, and carrying out repeated cleanings and subsequent thinnings in the regenerated crop; where seed-bearers are insufficient or natural reproduction fails, artificial methods of reproduction would be necessary. The most suitable method of opening the canopy to induce natural reproduction has not yet been determined by experience.

RATE OF GROWTH. The age of the padauk cannot be determined from annual rings. The rate of growth of natural padauk trees was calculated by Mr. Todd¹ in 1906 by measuring fifty trees on Chatham Island, in Port Cornwallis. This island was cleared of jungle in 1792 in order to establish a settlement, but was abandoned in 1796; thus the fifty trees measured must have been not more than 110 years old. The trees averaged 6 ft. 1.4 in. in girth,

¹ Draft Working Plan for the Forests of the North Andaman, 1906.

which gives a mean annual girth increment of 0.67 in. for an age of 110 years. At this rate an average tree might be expected to reach a girth of 7 ft. in 125 years; actually, however, the age of existing natural padauk trees 7 ft. in girth is probably higher, as the trees measured must have grown up under exceptionally favourable conditions. Measurements of 63 trees in a sample plot on Chatham Island, extending over three years, gave a mean annual girth increment for the period of 0.60 in.

The rate of growth in plantations is considerably faster. The following figures represent the mean girth and height (excluding suppressed trees) obtained from a series of measurements made in plantations of different ages in the Andamans:

Pterocarpus dalbergioides: rate of growth in plantations, Andamans.

Age. years.	Mean girth.		Mean height.
	ft.	in.	ft.
2	0	3	6
4	0	5	13
6	0	7½	20
8	0	10	27
10	1	0	34
15	1	5½	46
20	1	11	55
25	2	4	63
30	2	9	70

Some of the plantations were formed on land not typically padauk-bearing, and some remained insufficiently thinned for a time, so that on carefully selected land, if the plantations are regularly thinned, a more rapid rate of growth in girth might be attained.

4. *Pterocarpus macrocarpus*, Kurz. Burma padauk (as regards the correct pronunciation of this word, see under *P. dalbergioides*, p. 277). Vern. *Padauk*, Burm.

This is the true padauk tree, the other trees known by this name (*P. dalbergioides*, Roxb., and *P. indicus*, Willd.) having been designated padauk owing to their resemblance to the indigenous tree of Burma.

A large deciduous tree. Bark grey, exfoliating in irregular scales, exuding when blazed a bright red astringent gum resin similar in appearance to the kino of *P. Marsupium*. Leaves 6–9 in. long with seven to nine coriaceous leaflets.

Exceptionally the tree grows to a height of 90–100 ft. and a girth of 12 ft., but ordinarily it attains a height of 50–70 ft. with a clear bole of 20 to 40 ft. and a girth of 4½ to 6 or 7 ft. Mr. A. Rodger records a tree 12 ft. 3 in. in girth in the Paungadaw reserve, Ruby Mines division, Upper Burma. Large trees are often buttressed at the base and are nearly always hollow in the centre.

The padauk furnishes one of the most important timbers of Burma. The sapwood is light yellowish brown, small, the heartwood bright yellowish red to brick red, sometimes streaked with brown, hard, very strong and durable. In point of colour and decorative value the wood of the Burma padauk cannot compare with that of the Andaman padauk (*P. dalbergioides*), but for purposes where great strength and durability and good seasoning qualities are required

the former is one of the best of timbers. Its chief uses are for ordnance work, for which it is put to more uses than any other timber, wheel-work, frames and shafts of carriages, and agricultural implements. In Burma there is a large local trade in *padaungs*, or pieces usually 2 to 3 ft. long by 2 to 3 ft. in girth, used for the manufacture of cart-wheel naves. The stems yielding these pieces are commonly $3\frac{1}{2}$ to $4\frac{1}{2}$ ft. in girth at breast height.

DISTRIBUTION AND HABITAT. The padauk is found in suitable localities throughout the greater part of Burma from the 24th parallel of latitude in the Bhamo, Ruby Mines, Katha, and Shwebo districts southward to the Amherst district, and to a limited extent in South Tenasserim. On the east it extends, so far as Burma is concerned, to the borders of Tenasserim on the Thaungyin river and occurs in at least one locality east of the Salween river in the Southern Shan States. The principal padauk tracts of the upper Irrawaddy drainage occur in the Shwebo, Ruby Mines, and Mandalay districts, ascending to 2,000 ft. ; the tree extends along the Shan hills to the east of the Kyauksè, Meiktila, and Yamethin districts, and thence southward along the hills east of the Sittang river. It is common in the northern portion of the Pegu Yoma in the Yamethin, Toungoo, Magwe, and Thayetmyo districts, extending south to the Prome district on the west and hardly entering the Pegu district on the east : it is unknown in Tharrawaddy and Hanthawaddy. It is found in the Chindwin drainage up to about the 23rd parallel of latitude, being common in the Taungdwin reserve of the Myittha forest division, and occurs on the eastern slopes of the Chin hills and the Arakan Yoma, extending as far south as the Thayetmyo district. It is found scattered in the lower Salween drainage and is locally common in the Thaungyin and Ataran drainages.

The Burma padauk is usually found on undulating to hilly country, occasionally ascending to 2,500 ft. elevation. It occurs on a variety of geological formations, including gneiss and other metamorphic rocks, limestone, soft sandstone, and shale ; it is sometimes found on laterite, but usually in stunted form. The tree requires good drainage, and is found most commonly on sandy loam ; where the proportion of sand is in excess, although trees of large dimensions are produced they are usually unsound in the centre.

The padauk tree of Burma is found most typically in the drier types of upper mixed forest, often mixed with teak, some of its other common companions being *Terminalia tomentosa*, *T. Chebula*, *Xylia dolabriformis*, *Homalium tomentosum*, *Vitex glabrata*, *Dalbergia cultrata*, *Phyllanthus Emblica*, *Acacia Catechu*, *Shorea obtusa*, *Pentacme suavis*, *Sterculia villosa*, *S. versicolor*, *S. ornata*, and others, together with various bamboos, of which the chief are *Dendrocalamus strictus*, *Thyrsostachys Oliveri*, *Oxytenanthera albociliata*, *Cephalostachyum pergracile*, *Bambusa polymorpha*, and *B. Tulda*. It is noteworthy that working plans enumerations show that some of the sample plots richest in padauk are characterized by an abundant growth of *Oxytenanthera albociliata*, a bamboo which thrives on sandy soils. In the ordinary type of upper mixed forest, as exemplified in the Pegu Yoma, the padauk ordinarily seeks the upper and drier portions of the hill slopes, a common mixture being teak and padauk on the upper slopes and teak and pyinkado (*Xylia*) on the lower and moister slopes. Towards the northern extremity of the Pegu Yoma

padauk still persists, associated with such dry zone species as *Acacia Catechu* and *Tectona Hamiltoniana*, where the forest becomes too dry for teak. In the moister forests of this hill range the tree is absent. It extends in stunted form to the fringes of the dry zone of Upper Burma, for example on the dry outer hills bordering the Mandalay plain. The padauk sometimes occurs in *indaing* (dry dipterocarp) forest on laterite or sandy gravel, associated with *Dipterocarpus tuberculatus*, *Pentacme suavis*, *Shorea obtusa*, and other trees characteristic of this special type: here it does not attain large size. More commonly it avoids the usual *indaing* type and occurs in belts or patches of dry mixed bamboo forest of *Dendrocalamus strictus* between tracts of *indaing*, as in the southern part of the Ruby Mines district, where the tree is found on the broken ground along watercourses running through *indaing* forest, wherever the laterite soil gives way to richer soil. In this district, which produces some of the largest padauk in Burma, the tree reaches its best development in the drier parts of the bamboo forest, mainly of *Cephalostachyum pergracile* and *Thyrsostachys Oliveri*, on the lighter soils; here as a rule large growth denotes sandy soil and unsoundness in the timber, moderate growth denotes well-drained loamy soil and sound timber, and stunted growth denotes a heavy and unsuitable soil.

The padauk is not a gregarious tree, and as compared with teak, *Xylia*, and certain other trees it forms as a rule only a small proportion of the growing stock of the mixed forests in which it occurs. Working plans enumerations show that in the majority of cases the number of sound padauk trees 3 ft. in girth and over varies from 20 to 30 per 100 acres, and that padauk seldom forms more than $1\frac{1}{2}$ per cent. of the growing stock. Occasionally, however, padauk is abundant over comparatively small areas: thus in the Saing working circle of the Toungoo forest division a sample plot 47 acres in extent was found on enumeration to contain more than ten padauk trees 3 ft. in girth and over to the acre.

In the natural habitat of the padauk the absolute maximum shade temperature varies from 100° to 112° F., the absolute minimum from 40° to 52° F., and the normal rainfall from 35 to 180 in. or possibly more.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The tree is leafless for a time in the hot season, the new leaves appearing in April–May. The racemes of fragrant yellow flowers appear from March to May. The pods ripen in the cold season, and hang for some months on the trees, which are easily recognized when leafless by the flat round winged pods which are often present in large quantities; the pods fall for the most part during and towards the end of the hot season. The pods (Fig. 115, *a*) are 1.8–3 in. in diameter including the wing, finely pubescent, light greyish brown when ripe, the central portion hard and bony, containing usually one, more rarely two, seeds. About 650 to 900 pods weigh 1 lb. The seeds are dolabriform, reddish brown, 0.4–0.5 in. long, with a leathery testa. Although the pods are often produced in quantity the germinative power of the seed is comparatively low. This fact seems to require further inquiry: it has been suggested that the seed of pods which have hung long on the tree loses its germinative power, and that if fresh seed were collected a higher percentage of fertility would result, a point which requires verification. Various samples of seed collected in March were found

to be of poor quality, and possibly seed should be collected earlier in the season.

GERMINATION (Fig. 115, b, c). Epigeous, resembling that of other species of *Pterocarpus*. One pod produces one or more rarely two seedlings. The radicle issues from the side of the pod opposite the stalk, bending downwards into the ground. The pod is either left on or in the ground, the cotyledons being extricated by the arching of the hypocotyl, or is carried up above ground, falling with the expansion of the cotyledons. The testa remains within the pod.

THE SEEDLING (Fig. 115).

Roots: primary root long, moderately thick, terete, tapering, wiry to woody: lateral roots moderate in number, fibrous, distributed down main root: nodules present. **Hypocotyl** distinct from root, 0.5–0.7 in. long, tapering downwards, glabrous. **Cotyledons** sub-sessile or shortly petiolate, foliaceous, somewhat fleshy, 0.8–1 in. by 0.3–0.4 in., unequally ovate oblong, apex rounded, base obliquely obtuse, entire, green, glabrous, venation arcuate reticulate. **Stem** erect, terete, zigzag at the nodes, green, with minute adpressed hairs. **Leaves** alternate, petiolate, first 6–8 simple, usually followed by one or more trifoliate leaves, then leaves with four or more leaflets. Stipules 0.15–0.4 in. long, linear acuminate, minutely hairy. Simple leaves with petiole 0.15–0.8 in. long, tomentose, petioles short in early leaves, longer in subsequent ones; lamina of first 1–3 leaves 0.25–0.6 in. long, that of succeeding leaves becoming larger, up to 3 in. by 2.3 in., broadly ovate to orbicular, obtuse or acute, mucronate, base rounded or cordate, entire, glabrescent with scattered hairs or with hairs on the principal veins. Compound leaves with leaflets alternate; petiolules up to 0.1 in. long; lamina broadly ovate, acuminate, base rounded or slightly cordate, entire, silky hairy before expanding, becoming glabrescent or glabrous; terminal leaflet larger than lateral ones, up to 3 in. by 2 in.

Under favourable conditions the growth of the seedling is fairly fast, nursery-raised seedlings in Burma showing a height of 8–12 in. in two months. The growth of natural seedlings is slower. A long taproot is developed early, and reaches a length of about 8–10 in. in two months. As regards the factors which influence the development and survival of the seedling, this species bears a close resemblance to other species of *Pterocarpus* in so far as the early development of the seedling is concerned. Thus as regards the germination stages, where pods lie on the surface of the ground the radicles are subject to the attacks of insects and birds, while if exposed to a hot sun they are very apt to dry up. Germination is found to be greatly favoured if the pods are covered with earth or protected from the sun; this has been corroborated by observations in the forest, to the effect that the early development of the seedlings is favoured where the pods lodge behind clods of earth or stones, or are sheltered by low cover. Loose soil greatly favours the growth of the seedling. In Burma young plants suffer much in nurseries from the attacks of crickets, and in plantations from damage by weevils, which kill off the young shoots by ringing the bark. Young plants also suffer much from browsing by deer. Frost does not occur in the natural habitat of the tree, and, as might be expected, the seedlings are very sensitive when grown in localities subject to frost; young plants have never survived the winter at Dehra Dun. Seedlings repeatedly burnt back have the power of sending up new shoots from a permanent thickened root-stock.

SILVICULTURAL CHARACTERS. The padauk tree is a light-demander,

though possibly it is not so exacting in this respect as the teak. Although it grows best on deep well-drained porous soils it is not exacting as regards soil

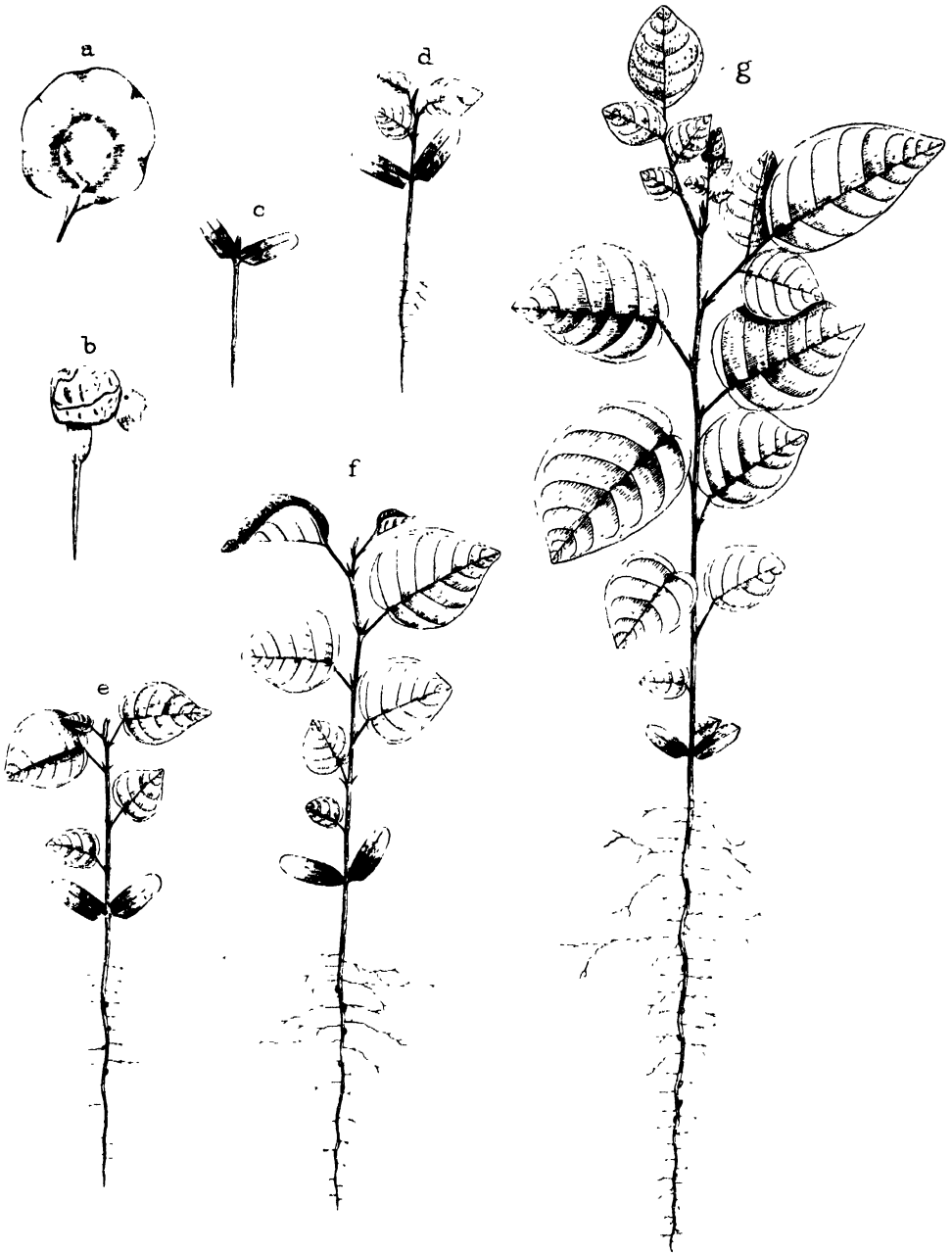


FIG. 115. *Pterocarpus macrocarpus*. Seedling $\times \frac{3}{8}$.

a, fruit ; *b*, *c*, germination stages ; *d*-*g*, development of seedling during the first season.

provided the drainage is good, since it is sometimes found in dry localities with poor shallow soil, though in such places it is stunted.

NATURAL REPRODUCTION. As a rule natural reproduction is reported to be good only in rather dry open forests, and is scanty or absent in moist

forests where the cover is denser. This appears to indicate that natural reproduction of this species, like that of the Andaman padauk, cannot establish itself under the suppression of low cover, and requires an abundance of light. Low cover, however, appears to favour germination and the early development of the seedling. Under natural conditions germination usually takes place during the early showers preceding the rainy season, and seedlings appear most commonly under the shelter of clods of earth, stones, &c. Mr. C. G. Rogers¹ records having observed in the Pyinmana forests one-year-old natural seedlings in an area where *Bambusa Tulda* had flowered recently. On the whole, natural reproduction in Burma is reported to be markedly deficient.

ARTIFICIAL REPRODUCTION. Attempts to form padauk plantations have been made in various parts of Burma, as a rule with little success, while the experimental dibbling of pods has proved a failure. Efforts to create plantations by transplanting nursery-raised plants, as well as by the *taungya* method of sowings in conjunction with field crops, have not been successful, partly owing to the poor germinating power of the seed and partly owing to damage by deer and by weevils. An experiment in sowing seed in small patches 6 ft. apart along a strip cleared of jungle proved equally unsuccessful. Mixtures of padauk with teak by the *taungya* system have also proved a failure, the teak rapidly outgrowing and suppressing the padauk. Most success has been attained by sowing the pods not later than April.

SILVICULTURAL TREATMENT. Hitherto padauk has been worked under selection fellings, the exploitable girth usually being fixed at 6 ft., and in the Ruby Mines forest division at 7 ft. and 7½ ft. in favourable localities. It will not be possible to devise a satisfactory method of silvicultural treatment until more is known regarding the measures necessary for securing successful natural or artificial reproduction. At the best this species can be regarded as only secondary to the teak wherever the latter will grow satisfactorily, since the teak grows faster, produces a larger out-turn, and is of greater value than the padauk.

RATE OF GROWTH. Detailed figures regarding the rate of growth of padauk are not yet available, and estimates based on ring-countings are unreliable owing to the indistinctness of the rings. Where padauk and teak have been tried together in plantations the latter has outgrown the former.

5. *Pterocarpus indicus*, Willd. Malay padauk. Vern. *Padauk*, Burm.

A semi-deciduous tree, attaining in Burma a height of 50 ft. or sometimes more, with a spreading crown of dark green foliage and drooping branches: the tree tends to form a short bole and to branch low down. Leaves 8–10 in. long with 5–9 leaflets. This is the padauk tree commonly planted along roadsides in Rangoon and other towns in Burma, and although commonly known as padauk in towns and stations it is not the true padauk tree of Burma, which is *P. macrocarpus*, Kurz, a tree typical of the forests. In Burma *P. indicus* is not important as a timber tree, but is largely planted for shade and ornament.

DISTRIBUTION AND HABITAT. This tree is believed to be indigenous in the Malay Peninsula and Archipelago, whence it has been introduced into Burma, where it has been largely planted in gardens and along roadsides and

¹ Inspection Note on Work of Burma Forest School, 1915.

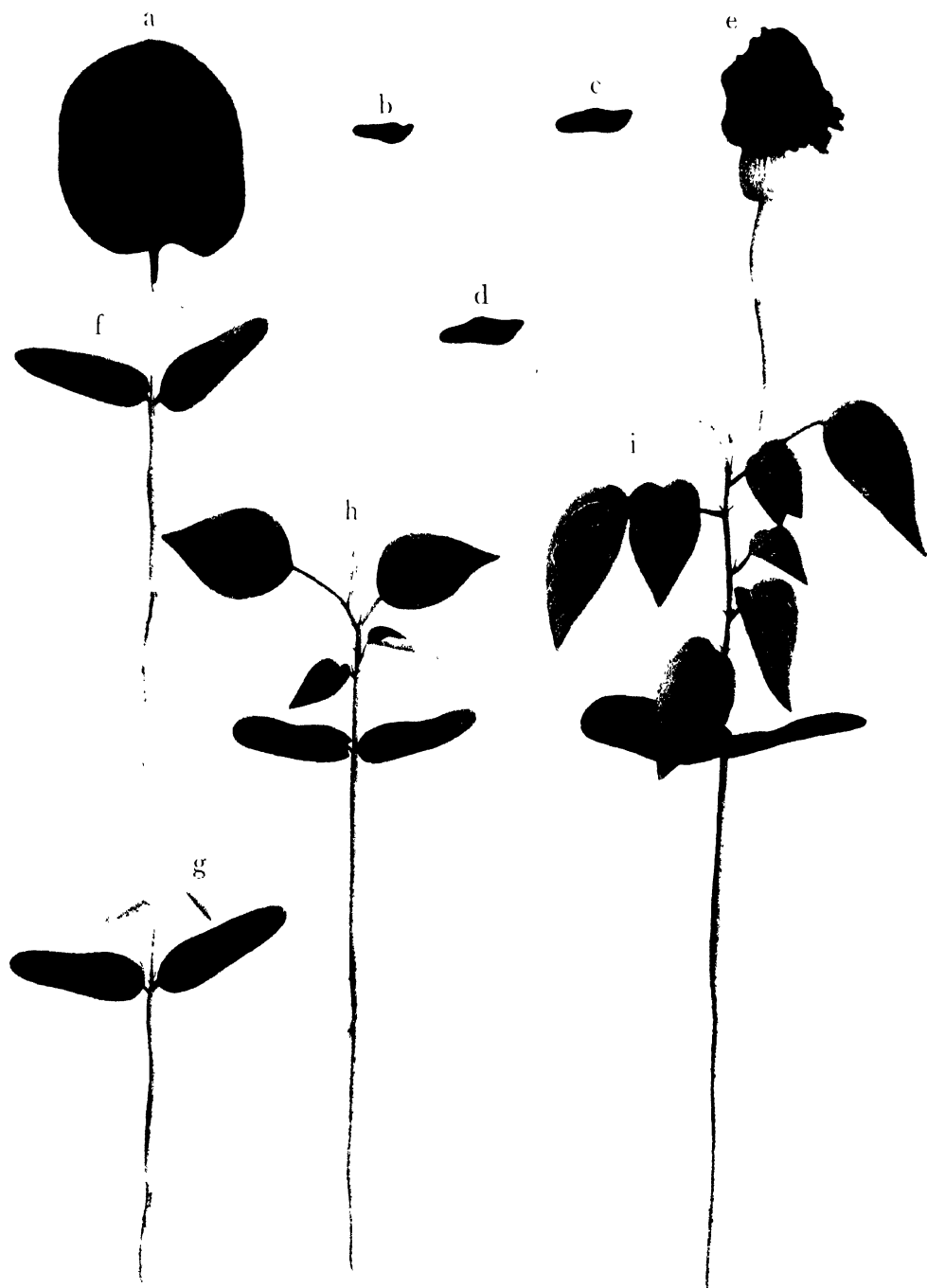


FIG. 116. *Pterocarpus indicus* —SEEDLING $\times \frac{3}{4}$

a—Fruit b—Seed c, d Germination of seed extracted from pod e—Germination under usual conditions
f, g, h, i Development of seedling during first season

avenues in the damper parts of the country. It has also been planted to a small extent about Calcutta and Madras. More recently it has been introduced into Bombay, where it promises to do well. The tree appears to thrive best in a tropical climate with a rainfall of not less than 60 in. It requires a deep well-drained soil, and does not thrive on stiff clay.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The tree is leafless or nearly so towards the end of the cold season, but is in full foliage during the hot season, when shade is most required. The panicles of fragrant yellow flowers appear in two or three separate flushes early in the rainy season, about May to July, and the pods ripen in the cold season, about January–February. The pods (Fig. 116, *a*) are orbicular, 1–2 in. in diameter, including the wing, the central part bony, containing one, or more rarely two seeds. The seeds (Fig. 116, *b*) are 0.4–0.5 in. long, dolabriform, flattened, brown, smooth, shining, with a leathery testa, brittle when dry. The germinative power of the seed, as in the case of *P. macrocarpus*, is comparatively low.

GERMINATION (Fig. 116, *c–e*). Epigeous, resembling that of other species of *Pterocarpus*. As a rule one seedling emerges from each pod, but sometimes two seedlings are produced. The radicle issues from the side of the pod opposite the stalk and bends downwards into the ground. The pod is either left in or on the ground, the cotyledons extricating themselves by the arching of the hypocotyl, or is carried above ground, falling with the expansion of the cotyledons. The testa remains within the pod.

THE SEEDLING (Fig. 116).

Roots : primary root moderately long, terete, tapering, wiry to woody : lateral roots numerous, fibrous, distributed down main root : nodules present. **Hypocotyl** distinct from root, 1.2–1.8 in. long, slightly compressed with a ridge down one side, fusiform or tapering slightly upwards, yellow at first turning green, glabrous or very minutely pubescent. **Cotyledons** sub-sessile or with short petioles up to 0.04 in. long, foliaceous, somewhat fleshy, 0.9–1.2 in. by 0.3–0.5 in., unequally ovate oblong, apex rounded, base semi-truncate, entire, green, glabrous, venation arcuate reticulate ; glands present on the hypocotyl between the cotyledons. **Stem** erect, terete, wiry, green, pubescent ; internodes 0.2–0.8 in. long. **Leaves** alternate, petiolate, first few simple, followed by several trifoliate and later by 5-foliate leaves. Stipules 0.1 in. long, earlier ones linear acuminate, later ones sub-falcate. Simple leaves with petiole 0.2–0.5 in. long, terete, pubescent ; lamina 0.6–1.9 in. by 0.3–1.2 in., cordate or broadly ovate, acute or acuminate, mucronate, glabrous above, sparsely pubescent beneath. Trifoliate leaves with rachis 0.7–1.5 in. long ; leaflets alternate, with short petiolules 0.04 in. long, broadly ovate, acuminate, mucronate, base rounded or obtuse, entire, glabrous above, sparsely pubescent beneath ; terminal leaflet 1.2–2 in. by 0.8–1.6 in., lateral leaflets 0.6–1.2 in. by 0.5–0.8 in.

As in the case of other species of *Pterocarpus*, it has been found that if the pods lie uncovered on the surface of the ground during germination the radicle is very subject to damage by insects and birds, while if exposed to the sun it is apt to dry up. Loose soil and protection from the sun favour the early development of the seedling. Frost is unknown in the natural habitat of the tree, and, as might be expected, the seedlings are very sensitive if grown in localities subject to frost : they have never survived the winter at Dehra Dun.

ARTIFICIAL REPRODUCTION. The tree is commonly propagated by large

cuttings, which should be planted in prepared pits in rather sandy soil early in the rainy season, or, if watering can be carried out, about the month of February. Nursery-raised plants are ready for transplanting at the commencement of the second rains, when they are rather more than one year old : planting can be most successfully carried out by transferring the seedlings to bamboo baskets during the first rains and planting them out in the baskets during the second rains.

5. DALBERGIA, Linn. f.

This genus is an important one silviculturally and economically. There are between thirty and forty Indian species, several of them straggling or scandent shrubs. Some of the trees are of little or no economic value, possessing whitish woods without heartwood ; the best known of these are *D. lanceolaria*, Linn., and *D. paniculata*, Roxb. Others are of great value owing to their dark-coloured ornamental heartwood. The two most important timber trees of the genus are *D. Sissoo*, Roxb., and *D. latifolia*, Roxb., which have been studied silviculturally in much greater detail than any of the others. Two others with ornamental woods, *D. cultrata*, Grah., and *D. Oliveri*, Gamble, have received preliminary study and are included below. *Dalbergia* pods are flat and indehiscent even during germination, with one or a few seeds, and those of several species are light and well adapted for dissemination by wind. Some at least of the species are known to produce root-suckers freely.

Species 1. *D. Sissoo*, Roxb. ; 2. *D. latifolia*, Roxb. ; 3. *D. sissoides*, Grah. ; 4. *D. cultrata*, Grah. ; 5. *D. Oliveri*, Gamble.

1. *Dalbergia Sissoo*, Roxb. Sissoo. Vern. *Shisham*, *sisso*, Hind. ; *T'ali*, Pb.

A large deciduous tree with a light crown ; bark 0.4-0.6 in. thick, grey, longitudinally and somewhat reticulately furrowed. Leaves compound, with 3-5 alternate leaflets. In favourable localities it reaches considerable dimensions, sound trees up to 8 ft. in girth and nearly 100 ft. high being by no means uncommon in the Bengal Duars ; in less favourable localities, as in the drier parts of the Punjab sub-Himalayan tract, it remains a comparatively small tree. The growth of the bole is as a rule somewhat crooked, and straight logs of any great length are difficult to obtain. The sissoo furnishes one of the most important timbers of India, and gives excellent fuel. The heartwood is brown with darker streaks, very hard, strong and durable : it is used for building, furniture, carts and carriages, wheel-work, gun-carriage wheels, carving, and a large number of other purposes. The sissoo is used in the tea-gardens of Dehra Dun as a shade tree and fertilizer for the tea-bushes.

DISTRIBUTION AND HABITAT. Throughout the sub-Himalayan tract from the Indus to Assam, and in the Himalayan valleys, usually up to 3,000 ft., but sometimes ascending to 5,000 ft. It descends the rivers for some distance into the plains. It is cultivated or self-sown in many parts of India. In its natural state the sissoo grows most typically on alluvial ground in the beds of rivers ; this alluvial type of forest is described below. The tree is, however, by no means confined to alluvial ground, and springs up freely wherever the soil is exposed, as on landslips, on hill-sides, on new embankments, and such places ; it springs up frequently along water-channels, as well as on grass-lands where the soil is exposed. It occurs in the Rawalpindi district in the

NATURAL RIVERAIN CROPS ON ALLUVIAL GRAVEL

Dalbergia Sissoo, Ramganga river, United Provinces



FIG. 117. Stage 1. In the foreground natural reproduction of sissoo up to 5 ft. in height springing up amongst grass, chiefly *Saccharum Munja* and *S. spontaneum* : older crop of sissoo in background.



FIG. 118. Stage 2. Young crop about 10 ft. high appearing over and beginning to suppress grass, *Saccharum spontaneum* and a little *S. Munja*.



FIG. 119. *Dalbergia Sissoo*, Ranganga river, United Provinces. Stage 4. Dense young crop averaging 15 ft. in height, grass killed out below trees.



FIG. 120. Stage 4. Crop 20 ft. high on bank of river.



FIG. 121. Stage 5. Pole crop 40 ft. high.

form of a straggling bush at an altitude of 5,000 ft., clinging to crevices on the sides of sandstone cliffs and spreading by means of root-suckers. In the Kangra valley it may be seen on hilly ground in somewhat open crops associated with *Pinus longifolia*, *Acacia Catechu*, and various miscellaneous species, ascending to 4,000 ft. Detrital boulder fans, torrent-beds, and taluses along the base of the outer hills are often covered with dense crops of sissoo. The tree avoids stiff clay, preferring a porous soil of sand, pebbles, and boulders : trees growing on clay are invariably stunted.

In the natural habitat of the sissoo the absolute maximum shade temperature varies from 102° to 120° F., the absolute minimum from 25° to 42° F., and the normal rainfall from 30 to 180 in., though the tree is of small size where the rainfall is less than 40 in. The sissoo probably reaches its finest development on the riverain tracts of the Bengal Duars, where the absolute maximum and minimum shade temperatures are about 103° and 35° F. respectively, and the normal rainfall varies from 130 to 180 in.

The alluvial sissoo forests are a characteristic feature of the rivers and streams of the sub-Himalayan tract and the outer Himalayan valleys. Here the tree grows gregariously in the beds of the rivers on the new alluvial land thrown up in the shape of islands or low banks formed of deposits of sand, shingle, and boulders, the sissoo forming forests either pure or mixed with *Acacia Catechu*. As the streams alter their courses or add fresh deposits, these forests are gradually elevated, and as this process continues, successive terraces of even-aged crops of different ages may be observed at various heights above river-level. Sometimes the advent of the sissoo is preceded by or is simultaneous with that of *Tamarix dioica*, while almost invariably grasses appear along with or immediately before or after the sissoo. In the western sub-Himalayan tract one of the most characteristic grasses through which the sissoo makes its way is *Saccharum Munja*, Roxb., the *moonj* grass, which sometimes occupies large stretches of rather dry sandy or shingly alluvium : other characteristic grasses associated with the early development of alluvial sissoo crops in this tract are *Saccharum spontaneum*, Linn. (the tufted sandy form), *Aristida cyanantha*, Steud. ex Trin., and *Triraphis madagascariensis*, Hook. f. When the sissoo crops come up with their characteristic density the grasses are gradually killed out, and frequently a dense undergrowth of *Adhatoda Vasica* appears. As the crop gets older and becomes thinned out by fire, felling, or other causes, miscellaneous species such as *Ehretia laevis*, *Holarrhena antidysenterica*, *Odina Wodier*, *Bombax malabaricum*, *Kydia calycina*, *Premna latifolia*, and others take the place of the sissoo, and a different type of forest comes into being. Often, however, this stage is never reached, for the rivers and streams frequently alter their courses and carry away every year considerable stretches of immature sissoo forest ; the wastage from this cause is at times considerable. Figs. 117 to 121 show the various stages in the development of riverain sissoo crops, and Fig. 123 shows a crop in process of destruction by erosion.

In the moist climate of the Duars the alluvial sissoo forests are characterized by the presence of a much more luxuriant growth of giant savannah grasses than is the case in north-western India. The chief species are *Saccharum arundinaceum*, Retz., *Erianthus elephantinus*, Hook. f., *Anthistiria gigantea*,

Cav., and in moister places *Phragmites Karka*, Trin. Where fire and grazing are excluded these grasses form a dense mass 12 to 20 ft. or more in height, and when fire does gain admission, as is almost bound to happen from time to time, the damage done is enormous; pole crops may be entirely destroyed, and even large trees may be killed. The result is that by the time the crop reaches maturity it often consists of widely scattered trees, many of which are badly damaged by fire. In these forests there can be little doubt that the admission of grazing as soon as the young crop is out of reach of cattle would be of much benefit in keeping down the rank growth of grass and minimizing the damage by fire. The most common companions of the sissoo in these tracts are *Acacia Catechu*, *Albizzia procera*, and *Bombax malabaricum*.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The leaves begin to fall in November, turning brown prior to falling; the leaflets fall separately. In cold situations the trees may be leafless by the beginning of December, while in some places the leaves have not all fallen by the end of January. The leaf-shedding is often very regular over the whole forest, all the trees being leafless and the sissoo woods in the river-beds having a characteristic bare grey appearance, contrasting strongly with the dark green foliage of the sal forest which so often occupies the high ground above the rivers. The young leaves appear in the second half of January or in the first half of February, and by the middle or end of February, when the new foliage has burst forth, the woods with their mantle of delicate green have a strikingly beautiful appearance, which is often intensified in combination with the vivid scarlet of the *dhak* trees (*Butea frondosa*), which flower when the foliage of the sissoo is young and fresh. The young delicate shoots are a favourite food of monkeys.

The young flower-buds appear with the new leaves, and the yellowish flowers, in axillary panicles of short racemes, open in March or April. The young pods form very rapidly, and by the end of April they may be as much as 2 in. long, pale green, and hanging in masses all over the tree: by July they are full-sized, but remain unripe and yellowish green until November, when they commence to turn brown, ripening towards the end of that month and during December and early January. The pods (Fig. 122, *a*), when ripe, are 2-3.5 in. by 0.3-0.5 in., pale brown, flat, 1- to 3-seeded, and like all *Dalbergia* pods are indehiscent. About 6,000 to 7,000 pods weigh 1 lb. The seeds (Fig. 122, *c*) are 0.25-0.3 in. by 0.15-0.2 in., reniform, flat, light brown, with a delicate papery testa.

Numbers of pods are blown off the trees from the time they ripen onwards, and are carried to some distance by the winds which blow down the gorges and rivers of the sub-Himalayan tract in the winter. Many ripe pods, however, remain on the trees until April, some even till May. Parrots destroy quantities of the pods while still green and unripe, and also to some extent after they ripen; nevertheless, the crop is ordinarily so abundant that the trees are laden with masses of ripe pods from November onwards.

Records of seed-years have been kept for a long series of years in different parts of the United Provinces and Bengal; these show that poor seed-years are very rare, and when they do occur are possibly due to some abnormal factor, such as was the case in the severe drought of 1907-8 in Oudh. With such rare exceptions the sissoo produces an abundant crop of pods each year.



FIG. 122. *Dalbergia Sissoo*—SEEDLING $\times \frac{3}{4}$

a - Fruits b—Germination under usual natural conditions c Seed d - i—Germination of seed
j - m -Development of seedling during first season

The trees produce fertile seed at an early age. Saplings two years old in a nursery bed at Dehra Dun flowered and produced a few pods, which were not tested; the pods produced the following year, that is, at an age of three years, were tested and the seed was found to be fertile. It has been recorded that seed from coppice-shoots eight years old in the Changa Manga irrigated plantation germinated indifferently; that obtained from coppice twelve years old in the same plantation germinated well, while seed from coppice nine years old in the Shahdera *sailaba* plantation also germinated well. More recently seed from coppice five years old in Changa Manga was found to germinate as well as that obtained from mature seedling trees.

The ripe pods can best be collected by men ascending the trees with bags or baskets and pulling the pods off in handfuls. The pods may also be beaten off the trees with sticks on to ground which has been previously swept. The seed, if stored in a dry place, retains its vitality to some extent for at least one year: seed from pods stored for one year was tested and found to have a fertility of 40 per cent.

GERMINATION (Fig. 122, *b*, and *d-i*). Epigeous. The radicle emerges from one end of the seed and curves downwards. The pod valves, which are brittle when dry, become soft when soaked by rain or river-water, and the radicle and young shoot have no difficulty in pushing their way through them, the testa being either carried up on the cotyledons, falling with their expansion, or left inside the pod. The hypocotyl arches in emerging from the pod, but soon straightens.

THE SEEDLING (Fig. 122).

Roots: primary root long, at first thin, afterwards thickening considerably, terete, tapering: lateral roots numerous, fibrous, distributed down main root: nodules present. **Hypocotyl** distinct from root, 0.8–1.3 in. long, terete, tapering slightly upwards, white turning green, pubescent. **Cotyledons**: petiole up to 0.05 in. long: lamina 0.4–0.5 in. by 0.25–0.3 in., foliaceous, somewhat fleshy, reniform with an angular projection on the basal half of the incurved side, apex rounded, base sagittate, entire, green, glabrous, obscurely 3-veined from the base. **Stem** erect, terete, thin, wiry, green, pubescent, zigzag at the nodes particularly in later stages; internodes 0.25–0.8 in. long. **Leaves** alternate, first leaf simple or trifoliate, subsequent leaves trifoliate, followed by 5-foliate, or occasionally one or two 4-foliate leaves. Stipules up to 0.1 in. long, sub-falcate, acuminate; stipels absent. Simple leaves with petiole up to 0.06 in. long; lamina 0.2–0.25 in. by 0.1–0.15 in., ovate, acute, mucronate, entire. Trifoliate leaves with rachis 0.2–0.5 in. long, slender, pubescent; stipels absent, petiolules up to 0.05 in. long; terminal leaflet 0.3–1 in. by 0.2–0.6 in., ovate elliptical or rhomboidal, apex acute or rounded, mucronate, entire, pubescent when young; lateral leaflets opposite, 0.2–0.5 in. by 0.15–0.4 in., ovate or elliptical, apex acute or rounded, mucronate, entire, pubescent when young. Subsequent 5-foliate leaves with leaflets similar but increasing in size, lateral leaflets alternate.

The factors influencing the development of seedlings and saplings are discussed below, and it will be seen that the rate of growth varies enormously according to the conditions under which the seedling grows. Where these conditions are at all favourable rapid growth takes place from the commencement, and continues in subsequent years. At Dehra Dun seedlings in a nursery bed well watered and weeded have attained in the first season a maximum

height of as much as 4 ft. 9 in., while seedlings regularly weeded but not watered have attained a maximum height of 3 ft. 1 in. Such growth is well above the average, and under unfavourable conditions, for example where there is a dense growth of weeds, a height of only a few inches may be attained in the same time.

The seedling produces a vigorous taproot which may reach a length of 9 in. in one month and 3 to over 5 ft. by the end of the first year. In the first season the taproot is somewhat fragile, with fairly numerous fibrous lateral rootlets; both taproot and lateral roots are covered with nodules. Under natural conditions in riverain deposits of shingle and boulders the long taproot becomes curiously flattened at intervals by contact with the stones as it twists its way down between them. The taproot of the seedling has considerable vitality. In order to thin out a line of seedlings in sowings at Dehra Dun at the end of the first season, the taproots of the plants to be removed were cut through an inch or two below ground-level. Next year the taproots left underground sent up new shoots, and the process of cutting was renewed; fresh shoots were, however, again sent up, and finally the roots had to be dug out.

The season's growth ceases in October–November, new growth commencing in February. The old leaves of seedlings commence falling in November and December, and may continue falling till January: many seedlings are leafless during December and January, but in moist situations the leaves may be retained until January or February. Natural seedlings are not so regular in their leaf-shedding as the adult trees in the neighbourhood. The seedlings are decidedly frost-hardy, and though in severe frosts they are sometimes killed back, they have good power of recovery. Young seedlings are particularly sensitive to drought, and suffer much if there are intervals of dry hot weather during the first rainy season. The whitish mildew fungus *Phyllactinia corylea* attacks the leaves of young plants of different ages as well as those of older trees. It is prevalent towards the end of the year, not long before the leaves fall, and is therefore probably less noxious than it would otherwise be. The seedlings are browsed by cattle, goats, deer, and hares, the damage done being at times considerable. In grassy land rats gnaw through the taproots and may kill the plants.

Factors affecting development of seedlings and saplings. The factors affecting the development of sissoo plants during the first few years have been studied in considerable detail by means of a large number of experiments carried out at and near Dehra Dun. The chief factors influencing this development are: (1) abundance of light; (2) sufficient growing space; (3) porosity of soil; (4) freedom from weeds; (5) a plentiful supply of water. As regards light, experiments carried out under varying shade conditions showed that under shade which is fairly dense the seed germinates satisfactorily, but the seedlings die off before the first rainy season is well advanced. In full light the development is always better than under partial shade. The effect of growing space on the development of saplings is seen in the manner in which the more vigorous members of a young crop take the lead from the first season and suppress the remainder. Experiments in thinning line sowings resulted in a much more satisfactory development than in the case of lines left unthinned; it was found



FIG. 123. *Dalbergia Sissoo*, pole crop, mean girth 10.2 in., mean height 30 ft., on elevated river-bank subject to erosion, Dehra Dun, United Provinces : trees infested with climber *Dregea volubilis*.



FIG. 124. Riverain forest of *Dalbergia Sissoo* and other species killed by excessive deposits of silt, Raidak river, Buxa, Bengal.

that in order to ensure the best results the thinning should start not later than the end of the first season, and should be repeated annually for a few years. Porosity of soil has a marked effect on development : on stiff clay the plants always remain stunted. The beneficial effects of soil-aeration resulting from periodic loosening of the surface soil combined with the eradication of weeds have been demonstrated in a marked degree in experiments at Dehra Dun, the results of which are given on the next page : these results refer to two separate sets of experiments : (A) broadcast sowings in Surajbagh garden ; and (B) line sowings in Kaunli garden. It was found that the effects were most marked in the first season, less so the next year, and least of all subsequently. Irrigation, as these experiments show, also has a decided effect on the growth of seedlings and saplings, as well as of trees, but in the young stages the effects of irrigation are largely discounted if weeding is not carried out : indeed weeding and loosening of the soil give much better results than irrigation without weeding, and in some cases the results attained by unirrigated sowings are not much inferior to those attained by irrigated sowings where weeding and loosening of the soil are carried out in either case.

SILVICULTURAL CHARACTERS. The sissoo is a strong light-demander ; in the dense crops which it often forms the more vigorous trees tend to suppress and kill out the weaker ones. It is decidedly frost-hardy : the leaves are sometimes affected by severe frost, but the tree is not seriously injured. In the abnormal frost of 1905 in northern India the trees suffered comparatively little damage, except that there were numerous cases of frost-crack in the plantations of the Lahore district. Seedlings are sensitive to drought, but in its natural state the tree is fairly hardy ; in the abnormal drought of 1907 and 1908 in Oudh the alluvial sissoo forests suffered comparatively little damage, though possibly they may have had the benefit of the river-water during the dry period. In irrigated plantations, as might be supposed, the trees die if the water-supply is cut off for any length of time.

Sissoo plants are readily browsed by cattle, goats, and camels ; where grazing is prevalent, seedlings and saplings are browsed down year after year, and coppice-shoots assume a dense bushy growth. The sissoo is not particularly fire-resistant, and the forests suffer greatly where there is much inflammable grass present.

It has already been noted that the sissoo will not tolerate stiff clay, and requires porous well-aerated ground for its proper development. In the sub-Himalayan tract sissoo forests, situated as they are in the neighbourhood of rivers, are occasionally killed by the accumulation of fresh deposits when the rivers change their courses (see Fig. 124) : these deposits no doubt deprive the roots of air and possibly prevent the action of bacterial agencies, thus causing death. Considerable mortality is caused annually by the mechanical action of rivers in eroding the banks and uprooting and sweeping away the sissoo trees, often before they attain marketable size.

Of fungoid pests the mildew fungus *Phyllactinia corylea* has already been mentioned as attacking the leaves of seedlings and saplings as well as of older trees ; it has not yet been noticed to cause any serious injury. A much more dangerous fungus is *Fomes lucidus* (Leys), Fr., which is the cause of much

Dalbergia sissoo : results of experimental sowings, Delhra Dun.

A. Broadcast sowings in Surajbagh garden.

Five plots, each cleared of weeds, dug up and levelled : seed sown in March.

Plot No.	Treatment.	End of 1st year.	Maximum height-growth.	End of 3rd year.	Condition.
1	Thoroughly irrigated, weeded, and soil loosened periodically	4 ft. 9 in.	End of 2nd year. 13 ft. (Girth at 1 ft. from ground 6.4 in.)	19 ft. 7 in. (Girth at 1 ft. from ground 1 ft. 3.5 in.)	Vigorous.
2	{ Weeded and soil loosened periodically Irrigated	3 ft. 2 in.	9 ft. 7 in.	14 ft. 10 in.	A vigorous crop.
3	{ Not weeded Less freely irrigated	10 in.	1 ft. 9 in.	5 ft. 6 in.	Development impeded by growth of weeds and grass ; plants much less vigorous than in plot 2. The larger plants only where weeds scanty.
4	{ Weeded and soil loosened periodically Not irrigated	3 ft. 1 in.	6 ft. 3 in.	9 ft. 10 in.	A dense vigorous crop, in need of thinning.
5	{ Not irrigated Not weeded	9 in.	1 ft. 8 in.	4 ft. 8 in.	Development impeded by growth of weeds and grass ; plants much less vigorous than in plot 4. The larger plants only where weeds scanty.

B. Line sowings in Kaunli garden.

Four lines, cleared of weeds, hoed up, and levelled : seed sown in May. In the irrigated lines seed sown along base of ridge thrown up along the side of irrigation channel.

Plot No.	Treatment.	End of 1st year.	Dimensions.	End of 3rd year.	Condition.
1	{ Weeded and soil loosened periodically Irrigated	Maximum height 3 ft. 9 in.	End of 2nd year. Height 1 ft. 2 in. to 12 ft. 6 in.	Average height 6 ft. 6 in. Maximum height 16 ft. 11 in. Maximum girth at 4½ ft. = 7 in.	Vigorous ; line well filled.
2	{ Not weeded Less freely irrigated	Maximum height 8 in.	Height 10 in. to 5 ft. 11 in.	Height 3 ft. 8 in. to 13 ft. 3 in.	Large plant at end of line free of weeds. Plants otherwise irregularly scattered with poor development.
3	{ Weeded and soil loosened periodically Not irrigated	Maximum height 1 ft. 10 in.	Height 1 ft. 4 in. to 9 ft. 3 in.	Maximum height 13 ft. 10 in. Maximum girth at 4½ ft. = 4 in.	Vigorous : line well filled.
4	{ Not irrigated Not weeded	All killed except a few weakly seedlings	One surviving, height 9½ in.	None surviving.	

mortality among sissoo trees in plantations and elsewhere ; it is particularly prevalent in the Changa Manga plantation in the Punjab, where it has spread rapidly within recent years and killed out large numbers of trees of all sizes as well as coppice-shoots and root-suckers. The same fungus is very prevalent in tea-gardens near Dehra Dun, and is probably the cause of mysterious deaths noticed among sissoo trees in various other localities. The life-history of this fungus, in its relation to the sissoo, has not yet been studied in detail, nor have successful preventive or remedial measures for dealing with it yet been devised ; it is tolerably certain, however, that it is capable of spreading below ground, since trees showing progressive stages of attack are frequently found in rows. In Changa Manga affected trees are cut out as far as possible, and the large bracket-like sporophores which appear round the bases of the trees are removed. A preventive measure indicated by the tendency of the fungus to spread underground would be to grow the sissoo trees in mixture with other species and not in too close proximity to each other. This fungus, which is widely distributed throughout the world, is usually considered saprophytic, but in addition to its undoubtedly parasitic form on the sissoo it has been found with strong presumptive evidence of parasitism on other species of trees in India, for example *Acacia arabica*, *Cedrela Toona*, *Areca Catechu*, and *Casuarina equisetifolia*, as well as on *Cassia siamea* in Java ;¹ it occurs, so far as is known in saprophytic form, on *Morus alba*. So serious has this fungus become in Changa Manga that experiments are on foot to ascertain what other species of useful trees are able to thrive there, since it is realized that it may be necessary largely to supplement the sissoo with other species.

Among phanerogamous parasites, *Loranthus longiflorus* is very prevalent on the sissoo, every tree being infected in some localities ; badly attacked trees succumb, the parasite then dying for want of sustenance. Alluvial sissoo forests are sometimes badly infested with the climber *Dregea volubilis*, which twines round the stems and over the tops of the trees, pressing down on the crowns and causing the trees to become stunted and badly shaped (see Fig. 123) ; the damage starts at an early stage in the life of the crop. Another fairly common climber in these forests is *Cryptolepis Buchanani* : though somewhat harmful, it is not so injurious as *Dregea volubilis*. Various climbers characteristic of other types of forest at times infest the sissoo forests, *Acacia pennata* being among the most noxious. Wind is at times a source of danger, uprooting the trees, particularly standards in recently felled coupes. This form of damage is most prevalent in irrigated plantations, where a superficial root-system is induced and the soil is kept in a soft condition by the water. Trees attacked by fungus at the base are also apt to be thrown by wind.

The roots of the sissoo are dimorphous, comprising nutrition roots without buds, penetrating downwards into the ground, and long horizontal roots with buds, from which suckers are produced. The seedling produces a long taproot at an early age ; this thickens considerably during the sapling stage, becoming much gnarled and twisted by contact with boulders. In the meantime lateral roots are thrown out ; the original taproot often dies off in part and forms nothing more than a short thick gnarled mass in which boulders and pebbles

¹ E. J. Butler in Ind. Forester, xxxv (1909), p. 514.

are often embedded : this taproot is sometimes thicker than the bole itself, and may consist of several branches with numerous subsidiary fibrous nutrition roots. The lateral roots may attain considerable length and thickness ; a tree 3 ft. 8 in. in girth in the Siwaliks was found to have lateral roots up to 30 ft. in length. The lateral roots spread at a depth of a few inches to about 2 ft. below ground surface, frequently sending up root-suckers, more especially where the roots have become exposed. The felling of the trees, particularly if carried out at or below ground-level, often results in a plentiful crop of suckers, the production of which may be stimulated by exposing the roots at intervals. In the Changa Manga plantation, however, this form of reproduction has proved far less successful than that obtained from stool-shoots.

The sissoo coppices vigorously, often sending up masses of shoots, some from the cambium round the edge of the cut surface and some from the side of the stool. It is not certain up to what age or size the tree will coppice successfully ; this probably depends on the vigour of individual stools and on other conditions. In Changa Manga trees are known to coppice well up to an age of at least twenty years. It has been noticed that the stumps of some trees cut out in thinnings in a plantation thirty years old in the Gorakhpur district, United Provinces, produced numerous coppice-shoots, though many failed to produce them ; this is, however, hardly a fair test, since many of the trees removed would naturally have been less vigorous members of the crop, while the stumps in a thinned crop are not exposed to the favourable light conditions obtaining in a coppice coupe. Observations extending over some years in sample plots in the Changa Manga plantation have shown that the growth of coppice-shoots from untrimmed stools is in no way inferior to that obtained from trimmed stools, and the practice of trimming stools in that plantation has therefore been given up ; in either case it was found that the stools rotted and the shoots produced independent root-systems. Some statistics of the rate of growth and out-turn of coppice are given below.

NATURAL REPRODUCTION. The light flat pods are disseminated in non-riverain tracts by wind and in riverain tracts either by wind or by water. It is sometimes stated that the seed has a hard testa which prevents its germination without prolonged soaking, and that this accounts for its usual occurrence in river-beds, where it receives long immersion in water before germinating. This is not correct, for the seed has an extremely delicate papery testa and not a hard one, and the pod valves when moistened quickly become soft enough to permit the germinating seedling to break through them without difficulty. The bulk of the pods reach the ground from the beginning of December till the end of April, and lie until they become sufficiently soaked to cause germination ; this happens normally when the monsoon rains commence in June and July. If continuous heavy rain or river floods occur earlier in the season the seeds may occasionally be found germinating not long after the pods fall, but unless the seedlings receive sufficient water to keep them alive during the dry weather preceding the monsoon, which is seldom the case, they invariably die of drought. It may be said as a general rule that germination commences at the beginning of the monsoon as soon as the pods have been sufficiently

soaked by rain. That the river floods assist in stimulating germination is no doubt true, but my own observations lead me to the conclusion that rain is a more important factor, for numerous germinating seedlings will be found early in the rains in riverain tracts in places well above the reach of floods ; few if any of these, however, survive under trees or in the presence of weed-growth or heavy grass such as ordinarily springs up on the older and higher land. In the subsequent establishment of the young crop in riverain tracts the percolation of river-water is undoubtedly of great importance. The factors which favour the development of seedlings and saplings have already been alluded to ; the open alluvial sandy and shingly river deposits of the sub-Himalayan tract present extremely favourable conditions for this development, namely full light, a highly porous soil, freedom from weeds, and as a rule sufficient moisture in the soil to tide over the dry season. On the new river-deposits the young plants are very commonly found making their way through grass, but the grasses on these sandy and shingly formations are usually in somewhat widely separated clumps (e. g. *Aristida cyanantha*, *Saccharum Munja*, and *S. spontaneum*) ; there is abundance of room for the seedlings to make their way, the grasses performing a useful function in affording side protection against the sun. The long taproot of the seedling is of great importance : not only does it secure the young plant from being washed away, but by the time the floods subside and the river-bed dries up on the surface it has established itself in the moister layers beneath, where in many cases the water from the river reaches it by percolation.

In non-riverain tracts the sissoo regenerates on newly exposed ground where weed-growth is scanty or absent, provided there is abundance of light. Thus crops of seedlings may be seen appearing on new embankments, landslips, heaps of stones, and such places, and in grassy tracts in places where the soil has been exposed by pigs grubbing up the soil. On abandoned cultivation the sissoo sometimes springs up in quantity if it succeeds in outgrowing weeds. Along the sides of water-channels saplings frequently appear, the water stimulating their growth sufficiently to enable them to overtop the weeds before they are suppressed. Experiments at Dehra Dun have shown that drought is a fruitful cause of mortality among natural seedlings, particularly if the pods lie on the surface of the ground without becoming covered, in which case large numbers of seedlings die off during germination. Another common cause of mortality in damp situations under shade is the rotting of seedlings during the first rainy season ; apart from the effect of the shade, this is undoubtedly a common cause of mortality where seedlings appear under cover of trees or undergrowth. In short grass germination takes place freely and the mortality is not so great, but the subsequent development of the seedlings is slower than on exposed ground. Dense weed-growth entirely prevents the establishment of regeneration. A remarkable instance of this was observed near the Sankos river in Goalpara, Assam. Sissoo saplings were found to be numerous on the unprotected side of a straight fire-line and practically absent on the protected side : both sides of the line were open to grazing. The explanation of this somewhat anomalous result was that owing to the presence of much grass on the unprotected side the damage by grazing was less than it would otherwise have been, while owing to the effect of grazing

in keeping the grass short, damage by fire was slight : on the fire-protected side, however, a comparatively heavy undergrowth was induced which effectually prevented the regeneration of the sissoo.

In spite of this somewhat exceptional example, fire and grazing are ordinarily most inimical to the establishment of natural reproduction. An instance of the adverse effect of grazing in this respect may be quoted in the case of a demarcated plot 200 square ft. in area in a river-bed in the Siwaliks, containing when laid out 1,562 seedlings one year old, with a maximum height of 6 in. ; this plot, which was in a grazed area, was kept under observation for five years, at the end of which time only eight seedlings with a maximum height of 8 in. survived, most of the remainder having been destroyed by grazing. For three years the seedlings lingered chiefly in tufts of tall grass, where they were protected from cattle, but these eventually died of suppression. Saplings which are kept down by grazing present a typical bushy appearance, forming strong root-systems and sending up numerous root-suckers which are themselves browsed down, so that a dense low bushy growth of sissoo may cover considerable stretches ; instances of this are fairly common in the Duars.

ARTIFICIAL REPRODUCTION. The sissoo can be grown from ordinary cuttings or from root cuttings. Such methods, however, are not in general vogue, as the tree can be raised so easily from seed. Plantations of root-suckers have proved highly successful in the dry climate of the Etawah district, United Provinces, and this form of propagation is worth further attention. In selecting sites for plantations care should be taken to avoid stiff clay soil, on which the trees, if they survive, remain stunted. Irrigation promotes the most rapid growth, and in the Punjab irrigated plantations, of which the oldest and most important is the Changa Manga plantation, have been in existence for many years and are being extended considerably. An account of the methods adopted in forming and working irrigated plantations is given below. Natural irrigation, in whole or in part, is secured in the case of *sailaba* plantations, formed on alluvial land adjacent to rivers, which receives occasional flood water ; a short account of one of these plantations is also given below. It has already been shown, in connexion with the development of the seedling, that good results can be attained without irrigation provided thorough weeding with loosening of the soil is carried out until the plants are well out of the reach of weeds : indeed, it may be said that in any form of sissoo plantation thorough weeding during the early years is essential. This weeding should commence after the seedlings have sent down their taproots, and not during the germination stages, otherwise they are liable to be loosened and washed away by rain or exposed to drought. As regards the actual method of raising plantations, direct sowing is so much more satisfactory than transplanting that it is the only method to be recommended on a large scale ; and in order to facilitate weeding, line sowings are far preferable to any other form of sowing. Many existing plantations in different parts of India, it is true, have been raised by transplanting from nurseries, but in the majority of cases the success attained has hardly been commensurate with the high cost involved. As transplanting is sometimes necessary, however, for the filling of gaps or for roadsides, the best method of carrying out this operation,

as indicated by the results of numerous experiments at Dehra Dun, may be indicated.

Transplanting. The pods should be sown in drills in seed-beds of light soil thoroughly worked up, and lightly covered with earth. The sowing should be carried out well before the rains (March–April in northern India), and the beds should be regularly and copiously watered by hand or by irrigation; regular weeding and loosening of the soil is necessary. If small transplants are required the drills should be 9 in. apart, running across the beds in the usual way. If large transplants of the second year are wanted the lines should run longitudinally along the beds, and should be about 18 in. apart, and the plants should be thinned out towards the end of the first season; watering should be more sparingly done in the second than in the first season, in order to render the plants hardier. Transplanting with entire stem and roots is successful only with small plants early in the first rains, before the taproot reaches too great a length. Transplanting with pruned stem and roots has invariably given better results, not only as regards the percentage of success, but also as regards the vigour of the plants after transplanting. The stem should be pruned down to a height of about 2 in. from ground-level and the taproot to a length of about 6 in. if transplanting is done in the first rains, or about 12 in. if it is done in the second rains. Plants up to 7 ft. in height or more which have been treated in this way have been transplanted with complete success, vigorous new shoots being produced from the base almost immediately and soon attaining the height which the plants would have reached if they had not been interfered with. The chief danger to be feared after transplanting is drought, and if watering can be done until the plants are established it will help matters. If watering can be done winter planting, when the plants are leafless, gives good results.

Various degrees of spacing have been adopted in sissoo plantations in India. Anything more than 8 ft. by 8 ft. is generally found to be too wide, resulting in low branching and crooked growth: even this is on the wide side, and 6 ft. by 6 ft. is preferable though more expensive. Spacing 5 ft. apart in lines 10 ft. apart has been found satisfactory, as this facilitates weeding along the lines.

Mr. S. H. Howard¹ has described a successful method of transplanting seedlings from the nursery, which was tried in Gorakhpur in 1917. Under this method sowing in the nursery is carried out in April, May, or June, and the nursery beds are watered until the rainy season begins. The seedlings are regularly weeded and tended, and reach a height of 5 to 6 ft. by June of the next year, by which time they are ready to plant out. Planting holes about 2 ft. broad and 2 ft. deep are prepared in March, and in June the earth is returned to the holes. The plants are dug up carefully on a rainy and cloudy day, care being taken not to damage the roots more than is necessary. All the leaves are then pulled off and the leafless plants are planted out. After about a month the soil is worked up round the plants, and in November, or whenever labour becomes plentiful, the grass round them is pulled up and the soil worked. Some plants may die down for about a foot or 18 in., but new shoots develop below this point. This method is particularly well adapted

¹ Ind. Forester, xliv (1918), p. 137.

for planting grassy blanks, the plants being large enough to overtop the grass from the beginning.

Unirrigated line sowings. Various experiments with unirrigated line sowings have been carried out at Dehra Dun. The best results have been attained by line sowings in combination with the cultivation of field crops, the crop employed for experimental purposes being the lesser millet or *mandwa* (*Eleusine coracana*), which grew to a height of about 3 ft. or more. The lines of sissoo were sown along with the crop in June, and the latter was reaped in October. It was found that if the field crops were sown continuously over the area the sissoo sowings were a failure, the plants dying of suppression; excellent results, however, were attained by leaving clear lines 2 ft. wide, along the centre of which sissoo pods were sown and lightly covered with earth, the intervening spaces being occupied by the crop (see Fig. 125). A spacing of 10 to 12 ft. between lines is sufficient, and 1 lb. of sissoo pods should suffice for 200 ft. of line. The weeding of the lines is carried out by the cultivator while the crops are on the ground. Cultivation of field crops between the lines of sissoo can be carried out without difficulty for at least a second year; this saves the cost of weeding. In this as in other forms of line sowings the plants require to be thinned out regularly where necessary from the end of the first year onwards.

Unirrigated line sowings without the aid of field crops are carried out in the same manner as with field crops, the ground being cleared and the earth well loosened along the lines with a hoe or plough; subsequent success depends largely on intensive weeding, which is more troublesome and expensive than in the case of sowings with field crops. The pods should be sown not long before the commencement of the rains. In some localities weeding cannot be done in the rains for want of labour, and experiments were accordingly carried out at Dehra Dun to ascertain if sissoo plants in line sowings made in an area covered with tall grass, as opposed to weed-growth, would escape suppression during the rains and stand the sudden exposure when the grass was cleared from the lines after the end of the rainy season. The experiment proved quite successful, and gave an indication of the procedure to be followed in sowing up grassy savannahs if cultivation with field crops is not feasible. The first step is to clear the grass and partially eradicate it by ploughing or digging along the lines to a width of 2 or 3 ft. some time before the rains set in, the sissoo pods being then sown along the lines. As soon as labour is available after the rains are over the lines should be cleared of grass sufficiently to afford the seedlings full overhead light, and kept clear throughout the dry season, the soil along the lines being kept loosened and free of weeds. Care is necessary, in the selection of savannah ground for afforestation with sissoo, to avoid areas with clay soil, of which certain grasses (e.g. *Imperata arundinacea* and *Eragrostis cynosuroides*) are often indicators.

Irrigated plantations. The best examples of irrigated sissoo plantations are to be found on the plains of the Punjab, where land originally covered with dry scrub jungle of *Capparis aphylla*, *Salvadora oleoides*, and *Prosopis spicigera* has been made to produce flourishing plantations yielding a high out-turn of fuel and a fair quantity of timber. The oldest of these plantations is that of Changa Manga, watered by the Bari Doab canal in the Lahore



FIG. 125. *Dalbergia Sissoo*, unirrigated line sowings with the aid of field crops, 3½ months old, Dehra Dun.



FIG. 126. Changa Manga plantation : irrigated line sowings of sissoo 8 months old.

district. Originally an area of 780 acres was taken up in 1866, but large extensions have been made subsequently. In 1916 the plantation had a gross area, including roads, rest-house compound, &c., of 9,605 acres and a wooded area of 9,097 acres. Many different species were tried at first, and it was only after numerous experiments that sissoo was decided on as the most suitable species for furnishing the requisite supplies of good fuel and useful timber. Other irrigated plantations have been commenced in the Punjab within recent years. In 1918 there were six new plantations, either started or about to be started, namely Kot Lakhpat (1,965 acres) and Tera (837 acres) on the Upper Bari Doab canal; Chichawatni (10,930 acres) and Khanewal (17,708 acres) on the Lower Bari Doab canal; Pir Mahal (15,000 acres) on the Lower Chenab canal; and Daphar (7,200 acres) on the Upper Jhelum canal. The areas of the last two are roughly tentative; they had not been started in 1918.

The preliminary work of laying out an irrigated plantation is carried out by the Irrigation Department, which constructs the distributaries leading from the main canal. In the case of the newer plantations, for purposes of irrigation control the area is divided into *chaks* or main subdivisions, each of which contains several compartments. A compartment may comprise two or more irrigation 'squares', and may be divided by watercourses (*khals*) into fields for irrigation purposes. In the Changa Manga plantation there are no *chaks* or squares. The working scheme for the new Khanewal plantation in the Multan district prescribes compartments as nearly as possible 50 acres in area, each comprising two squares of 25 acres each: each compartment is divided into three fields watered by three secondary *khals*. Each *khal* has on either side of it, and running parallel and close to it, a *pasel* or subsidiary channel which takes water from the *khal* and distributes it into the plantation trenches: the construction of *pasels* obviates the necessity for making openings in the *khal* at more points than is necessary. In the new Khanewal plantation the dimensions laid down for the secondary *khals* are $\frac{4+3}{2} = 3\frac{1}{2}$ ft. mean breadth by 1 ft. depth, and those of the *pasels* are $\frac{2+1}{2} = 1\frac{1}{2}$ ft. mean breadth by 1 ft. depth. The ultimate irrigation trenches are 1 ft. by 1 ft. in section. In Khanewal and Kot Lakhpat they are dug 10 ft. apart, in Changa Manga 11 ft. apart, and in Tera 15 ft. apart, the distances being measured from centre to centre. The secondary *khals*, *pasels*, and trenches are dug by the Forest Department. The estimate of earth-work for a compartment of 50 acres in the Khanewal plantation is as follows:

		cub. ft.
3 secondary <i>khals</i>	1,980 ft. $\times$ $3\frac{1}{2}$ ft. $\times$ 1 ft.	= 20,790
7 <i>pasels</i>	1,980 ft. $\times$ $1\frac{1}{2}$ ft. $\times$ 1 ft.	= 20,790
196 trenches	990 ft. $\times$ 1 ft. $\times$ 1 ft.	= 194,040
Total		235,620

Various methods of carrying out the sowings and irrigating them have been tried, but the method now universally adopted as being the only really successful one is to throw up the soil excavated from the trench in the form of a ridge running alongside the trench; a small berm 3 or 4 in. wide, raised an inch or two above the level of the ground, is made between the trench and the ridge, and on this berm the seed is sown. As a rule 60 to 80 lb. of seed have been used per acre, but recently 40 lb. per acre has been tried in

Kot Lakhpat plantation and found to be sufficient. The best results are obtained by sowing from March to May ; sowing may continue till September, but the plants from the later sowings are less vigorous than those from the earlier ones. Figs. 126 and 127 show sowings one and two years old.

The success of the plantation depends largely on the extent to which irrigation can be carried out and the regularity with which it can be effected in the dry season. It is a recognized principle that field cultivation has prior claim to water, so that the plantations do not always receive as much as they should. In the Kot Lakhpat plantation experience so far has been that the maximum number of times an area may be expected to be flooded during the year of sowing is seven times, while the average is considerably less, some areas having received no water since the first year and the crop having died in consequence. As the plantation becomes older less water is required, but irrigation should never be suspended for any length of time, as the trees invariably die off : it must continue regularly throughout the life of the plantation. Irrigation is carried out as far as possible throughout the whole year, though it is scarcely necessary from November to February ; most water is required from April to June. The irrigation consists not only in filling the trenches but also in flooding the whole area above ground-level : young sowings, however, are not flooded, only the trenches being filled with water. In the Kot Lakhpat plantation the main channel which supplies the plantation is designed to flood the whole area between April 1 and September 30 to a total depth above ground-level equivalent to 3 ft. for the period, but actually the amount of water obtained may be considerably less. It is estimated that for a young plantation the minimum total depth of water possible during the hot weather months, April 1 to June 30, is about 1·7 ft. for the period, while if possible a depth of 2·5 ft. should be obtained : the latter is now arranged for as a minimum in Changa Manga. If the monsoon is favourable little or no irrigation may be necessary from July to October. In most parts of Changa Manga the effect of irrigation is to saturate the soil to a depth of several feet ; only on the higher parts is saturation not so deep.

Irrigation is the dominating factor in an irrigated plantation, the size of which has to be limited to the area which can be irrigated successfully during April, May, and June, when if flooding to a total depth of anything much less than 2½ ft. is not carried out failure is almost certain. All other works must give way to irrigation in order to seize the opportunity of obtaining water whenever it is available, workmen being taken off other works for the time being to attend to it. The watercourses and trenches are regularly reopened whenever necessary. The earth cleared from the trenches is thrown on to the spaces between them except where sowing is to be carried out, when it is heaped up in a ridge on one side.

The irrigated plantations of the Punjab are worked under the system of coppice-with-standards. The question of the rotation has not yet been finally settled. In the case of Changa Manga regular fellings were commenced in 1881-2, but owing to labour and other difficulties work under the working plans was always in arrears, and for practical purposes the plantation may be considered to have passed through two rotations, one of sixteen years and a second of twenty-two years up to 1918-19. In the latest revised working



FIG. 127. Kot Lakhpat plantation : irrigated line sowings of sissoo 2 years old.



FIG. 128. Changa Manga plantation : coupe recently felled, showing sissoo standards left and felling refuse on the ground.

plan¹ a rotation of twenty years has been adopted, from 1916-17 to 1935-6. In the case of the newer plantations it is proposed to sow up the whole area in fifteen years, but it may be decided later to adopt a longer rotation. In fixing the rotation it should be borne in mind that the value of the timber increases greatly with the size of the logs obtained : on the other hand, large numbers of standards disappear owing to windfall and to the fungus attacks already mentioned, while it is not always practicable to remove all dead material scattered over the area, for which reason it is unsafe to adopt too long a rotation. In the revised Changa Manga working plan trees are considered to be fully mature after three rotations, that is, in sixty years. The number of standards aimed at is 15 to 20 per acre. The dressing of stools in cutting the coppice has now been abandoned, as it has been found to possess no advantage. Figs. 128 and 129 show two coupes in Changa Manga.

The Changa Manga plantation affords an interesting example of the spread of a subsidiary species by the agency of water and of birds. Once sissoo had been decided on as the most suitable species the intention was to make the plantation one mainly if not entirely of that species, and although there exist survivals of various other kinds of trees experimented with, the plantation in its earlier days consisted almost entirely of sissoo. Among the species planted on a small scale was the mulberry, *Morus alba* ; the fruits of this tree are greedily eaten by starlings (*Pastor roseus*), which visit the plantation in large flocks at the time they ripen from the end of March to the end of April, and the seeds are widely scattered, particularly in the newly felled coupes, since the birds have a preference, as roosting places, for the standards left in these coupes. In addition the seed is largely spread by water during irrigation, and it is probable that the mulberry may have been introduced originally to a considerable extent from trees in the submontane tract by the irrigation canal : at all events, in some of the newly formed plantations the mulberry is making its appearance by this agency. The mulberry seed is spread to a limited extent by jackals and by human beings, but these are minor agencies. The mulberry being more shade-bearing and faster growing than the sissoo, and having a great capacity for regenerating, has spread throughout the plantation to such an extent that it now forms a considerably greater part of the crop than the sissoo, and were it not that special measures are taken to favour the sissoo it would be largely if not entirely ousted by the mulberry. At first the mulberry was looked on as a dangerous weed, but now it is regarded as a useful adjunct to the sissoo. Although its wood is of less value than that of the sissoo both as timber and as fuel, its more rapid growth compensates to some extent for this, while its shade-bearing character enables it to occupy ground under the sissoo which would otherwise be wasted, thus helping to swell the out-turn of the plantation. Fig. 130 shows mulberry coppice under sissoo standards. Silviculturally the mulberry acts as a useful soil-protector and promotes straighter and cleaner growth in the sissoo. In order to prevent the suppression of the sissoo and to maintain a sufficient proportion of that species, it is necessary to carry out repeated cleanings in the young coupes by cutting back the growth of mulberry in the interests of the seedling or coppice reproduction of the sissoo. Under the latest revised Changa Manga working

¹ Revised Working Plan for the Changa Manga Plantation, R. N. Parker, 1917.

plan the maintenance of the proportion of sissoo is provided for by clearing the mulberry and weeds in strips about 20 ft. wide and 100 ft. apart from centre to centre and cleaning repeatedly for three or four years along these strips. Three thinnings are also prescribed during the course of the rotation, at 6, 11, and 16 years of age respectively. Experiments have shown that natural reproduction of sissoo by seed can be obtained successfully merely by clearing the ground in newly felled coupes and carrying out periodical weedings and cleanings in order to free the seedlings which appear: a fair amount of reproduction is also obtained from root-suckers. Where further reproduction is required seeds are sown in the original lines alongside the trenches, which are reopened. It was formerly the practice to pile up the brushwood left after the fellings and burn it, but experience has shown that this is unnecessary, since it has been found to be cheaper and to cause less damage if the brushwood is merely piled up and left unburnt in the spaces between the trenches, in which case sufficient seedling and sucker reproduction comes up readily and the refuse rots within three or four years. Only where *kána* grass (*Saccharum Munja*) is very dense and the standards are few in number is burning carried out to facilitate the stubbing out of the grass, an operation which is necessary to prevent the suppression of young crops.

The following summarizes the year's programme of work in an irrigated plantation in the Punjab:

April to June. Irrigation, opening trenches, stubbing out *kána* grass.

July to September. Opening trenches, weeding, cleaning, stubbing out *kána* grass, and opening trenches in areas recently felled over.

October to December. House and road repairs.

December to March. Clearing silt, repairing watercourses, and opening trenches.

Some figures of yield from the Changa Manga plantation are given below under 'rate of growth and out-turn'. Owing to the amount of experimental work necessary at first, the cost of this plantation was considerably higher than it would have been if experience had not had to be bought. Estimates for new irrigated plantations can now be framed with a fair degree of accuracy. In the working scheme for the Khanewal plantation the rates adopted in the estimate are: (1) construction of main and branch watercourses, Rs. 0-10-6 per acre; (2) construction of secondary watercourses, *pasels*, and trenches, Rs. 12 per acre; (3) collection and carriage of seed, Re. 1 per maund (82 lb.); (4) sowing, Rs. 2-2-0 per acre. Further expenditure is estimated for in connexion with roads, buildings, boundaries, repairs to watercourses, irrigation rental (Rs. 2-12-0 per acre per annum), and other items. In the earlier years the land not required for sowing is leased for agriculture, the initial expenditure being thus recouped in part.

Mr. R. N. Parker has worked out, in the revised working plan, details showing the financial position of the Changa Manga plantation from its commencement in the year 1867-8 down to the year 1915-16, allowing interest at 4 per cent. per annum on capital expenditure. By the year 1881-2, when regular working was commenced, the capital invested, with interest added, amounted to Rs. 6,73,769, of which Rs. 1,25,499 represented the value of the



FIG. 129. Changa Manga plantation : coupe showing sissoo standards and coppice 6 months old.



FIG. 130. Changa Manga plantation : sissoo standards over mulberry coppice 16 years old.

land. By 1898-9 the financial position was at its worst, the accumulated arrears of interest amounting to Rs. 4,78,018. With the second rotation, however, the position began to improve, and by 1913-14 the whole of the arrears of interest had been paid off and the plantation had just paid 4 per cent. on all capital invested in it, leaving Rs. 17,710 as profit. The position continues to improve at a rate at which the whole capital could be paid off within a few years, leaving a property of great value.

An independent calculation made with the view of ascertaining the rate of interest yielded by the plantation by the end of 1913-14 determined the rate of interest to be 4.67 per cent. The method employed was to ascertain at what rate of interest (*a*) and (*b*) are equal, where (*a*) represents the value at the outset of the annual profits and of the present estimated value of the property less the value at the outset of the annual losses, and (*b*) represents the value at the outset of the original value of the property and of all capital expenditure incurred. In round figures the values with interest at 4.67 per cent. are as follows :

	Rs.
(a) Value at outset of annual profits and of present estimated value of property	4,18,200
Value at outset of annual losses	31,200
	—
Difference	3,87,000
(b) Value at outset of original value of property and of capital expenditure	3,87,000

This calculation probably errs on the side of safety : not only was the present value of the land over-stated, but no revenue was allowed for until the first fellings commenced in 1881-2, although the receipts up to that year exceeded Rs. 1,00,000 from grass, grazing, cotton cultivation, and other items.

These figures are sufficient to indicate that irrigated plantations formed and managed on rational lines have every prospect of yielding a fair return on the capital invested.

Sailaba plantations. These are plantations formed on the alluvial ground thrown up along the banks of rivers and subject, in part at least, to occasional flooding. The oldest plantation of this kind is the Shadera-Jugian plantation on the banks of the Ravi river near Lahore, where the rainfall is about 18 in. This plantation was commenced in 1865, and the area now amounts to some 1,400 acres. The soil is recent alluvium (*sailaba*) of a fairly light and sandy nature. The subsoil water at the driest season is about 6 to 15 ft. below the surface. A large proportion of the area is liable to inundation from the river during exceptionally high floods, but immersion is never long continued. Various methods of sowing and planting were tried when the plantation was formed ; these included sowing broadcast or in patches or lines of various spacing, as well as the transplanting of seedlings and root-cuttings. As far as can be ascertained from records the best results were attained by transplanting seedlings and by line sowings. Failures occurred mainly in water-logged places, while some damage was done by floods when the seedlings were small. It is interesting to note that the growth has been best in the more elevated portions where the water-level is some 12 to 15 ft. below ground surface. The system of management applied so far has been coppice-with-standards with a coppice rotation of fifteen years, 15 to 20 standards being left per acre. As in Changa Manga, mulberry has spread over the plantation,

TABLE 1. Normal growing stock of sissoo seedling crop

Age. years.	Number of trees per acre.	Mean diameter at 4½ ft. from ground. in.	Mean height. ft.	Solid volume of growing stock per acre.		
				Material over 2 in. diameter. cub. ft.	Faggots 1 in. to 2 in. diameter. cub. ft.	Brushwood under 1 in. diameter. cub. ft.
I Quality.						
5	1,028	3.5	21.2	198	18	20
10	350	6.5	38.7	765	63	77
15	130	9.3	52.8	1,600	126	160
20	88	11.7	62.0	2,642	196	265
II Quality.						
5	1,200	2.9	18.0	146	11	15
10	460	5.4	33.0	536	40	57
15	—	7.8	45.0	1,124	79	120
20	—	9.8	53.0	1,829	125	195
III Quality.						
5	—	2.3	14.8	112	8	12
10	570	4.5	27.4	402	27	43
15	295	6.4	38.0	823	53	87
20	230	8.1	45.4	1,310	83	139

TABLE 2. Yield of fuel, sissoo seedling crop

Yield of fuel from 1 acre clear-felled.

Age. years.	Material over 2 in. diameter, stacked volume. cub. ft.	Faggots 1 in. to 2 in. diameter, stacked volume. cub. ft.	Brushwood under 1 in. diameter, solid volume. ¹ cub. ft.	Total, solid volume. ¹ cub. ft.	Mean annual increment, solid volume. cub. ft.
I Quality.					
5	325	100	20	220	44
10	1,255	356	77	844	84
15	2,625	706	160	1,770	118
20	4,333	1,102	265	2,917	145
II Quality.					
5	247	69	14	167	33.
10	928	243	56	625	62
15	1,965	499	117	1,321	88
20	3,225	794	197	2,168	108
III Quality.					
5	184	46	11	123	24
10	660	157	40	442	44
15	1,350	303	82	902	60
20	2,150	468	130	1,434	71

Reducing factors.

100 cub. ft. stacked = 57 cub. ft. solid for fuel over 2 in. diameter.

100 cub. ft. stacked = 17 cub. ft. solid for fuel under 2 in. diameter.

Brushwood estimated at 10 per cent. of total out-turn.

Loss in conversion estimated at 7 per cent. of total out-turn.

increasing its yield ; in the young coupes the sissoo has to be protected against the mulberry by means of cleanings. Wind is a serious cause of damage, chiefly to standards left in recently felled coupes : the fungus *Fomes lucidus* has also been responsible for much mortality among the trees. As regards

¹ These are the figures as published : there appears to be a slight discrepancy on comparing some of them with the corresponding figures in Table 1.

in Changa Manga plantation.

Volume of normal series of age gradations in coupes of 1 acre each.							
Total of all classes. cub. ft.	Mean annual increment. cub. ft.	Material over 2 in. diameter.	Faggots 1 in. to 2 in. diameter.	Brushwood under 1 in. diameter.	Total of all classes.	Mean annual increment.	Age. years.
236	47	444	39	48	531	106	I Quality. 5
905	90	2,998	253	305	3,556	355	10
1,886	126	9,216	749	827	10,792	719	15
3,103	155	20,294	1,587	1,938	23,819	1,190	20
172	34	326	25	33	384	77	II Quality. 5
633	63	2,127	162	228	2,514	251	10
1,322	88	6,509	477	693	7,679	512	15
2,149	107	14,264	1,007	1,519	16,990	839	20
132	26	258	17	25	300	60	III Quality. 5
472	47	1,626	110	170	1,906	190	10
963	64	4,859	423	513	5,795	386	15
1,532	76	10,384	777	1,100	12,261	613	20

in Changa Manga plantation.

Yield of fuel from 1 acre with 15 standards reserved.					
Material over 2 in. diameter, stacked volume. cub. ft.	Faggots 1 in. to 2 in. diameter, stacked volume. cub. ft.	Brushwood under 1 in. diameter, solid volume. cub. ft.	Total, solid volume. cub. ft.	Mean annual increment, solid volume. cub. ft.	Age. years.
310	94	19	209	42	I Quality. 5
1,180	319	72	792	79	10
2,430	622	148	1,633	109	15
4,000	960	244	2,684	134	20
240	66	14	162	32	II Quality. 5
880	225	53	592	59	10
1,845	450	112	1,239	82	15
3,000	700	183	2,012	100	20
180	43	11	119	24	III Quality. 5
630	145	38	421	42	10
1,275	270	77	849	56	15
2,020	408	122	1,342	67	20

out-turn, this plantation compares favourably with Changa Manga, in spite of the fact that the latter is regularly irrigated; the out-turn during the first rotation amounted to 230 cub. ft. stacked per acre per annum, including brushwood, or 200 cub. ft. excluding it, as against about 160 cub. ft. for Changa Manga. During the first rotation the plantation yielded a net surplus of Rs. 9-6-7 per acre of wooded area per annum.

SILVICULTURAL TREATMENT. The silvicultural treatment of the sissoo in irrigated plantations has already been described; the system adopted in the Punjab is coppice-with-standards, seedling reproduction to replenish the existing crop being obtained both naturally, by clearing the ground and weeding the young crop, and artificially where necessary by sowing along the original lines. The value of a shade-bearer to mix with the sissoo has been alluded to. The mulberry serves this purpose well, provided it is kept in check

by the necessary cleanings. Other species might be suggested, such as *Eugenia Jambolana*, *Ougeinia dalbergioides*, *Schleichera trijuga*, and in moist places *Bischoffia javanica*.

The case of natural riverain forests presents some difficulty, owing to the unstable condition of much of the land on which they are situated. It is obvious that as long as the land is likely to disappear through erosion it is not worth while undertaking special regenerative operations on it; Nature carries out these herself by throwing up new land and producing new crops of sissoo in compensation for those destroyed. In such unstable lands the only course possible is to utilize all material as soon as it becomes marketable, by extracting all saleable dead and fallen trees at frequent intervals and all growing trees when they reach exploitable size. It is quite certain that the sissoo cannot as a rule be relied on to regenerate itself in the actual coupes, as these are usually covered with dense grass and weed-growth. Actually the riverain sissoo forests of the sub-Himalayan tract are worked for the most part either by selection fellings or, as in the case of some of the Ganges islands, by simple coppice on a rotation of twenty years, belts being left unfelled along the edges adjacent to the river. The correct procedure with regard to the working of riverain tracts as high forest appears to be to divide them into two classes: (1) unstable land subject to erosion; and (2) stable land, which seems to be reasonably safe from river action for many years. The unstable lands would be worked in the manner already indicated. On the unstable lands, on the other hand, special regenerative operations should be undertaken: it is difficult to see how this could be effected satisfactorily except by clear-felling with artificial reproduction, with or without the aid of field crops. With each revision of the working plan it may be necessary to transfer areas from the stable to the unstable class, and vice versa; the greater the proportion of land which can be allotted to the stable class the more profitable will be the working, since the more intensive treatment possible in this class must necessarily produce a higher return. Climber-cutting should be executed over both classes. In the stable class regular cleanings and thinnings will be necessary, but in the unstable class a large expenditure on such works is not justified. In the latter class, however, if the crops are in no immediate danger of being washed away, thinnings, especially if they pay their way, are most desirable in order to bring the crops more quickly to maturity; they could be made conveniently along with the principal felling under a short cycle of say ten years.

RATE OF GROWTH AND OUT-TURN. The rate of growth of sissoo varies so much according to conditions that it will be advisable to consider available statistics separately for: (1) irrigated plantations; (2) unirrigated (including *sailaba*) plantations; and (3) natural crops.

1. *Irrigated plantations.* Some figures have been given above, in connexion with the development of seedlings and saplings, showing the rapid growth of young plants where irrigation is combined with weeding, in one case a maximum height of nearly 20 ft. having been attained in three years. Figures of out-turn for mature irrigated plantations are as yet confined to the Changa Manga plantation, but here general averages are difficult to obtain owing to the varying yield in different localities, and to the fact that the crops

have been felled at different ages and that the mixture of mulberry has an appreciable effect on the yield.

The statements on pp. 312-13 give an abstract of a series of figures compiled by Mr. B. O. Coventry¹ from measurements of seedling crops in the Changa Manga plantation, made when the plantation was cut over for the first time.

It is estimated that in this plantation seedling trees reach a girth of 4 ft. on an average in about twenty-five to thirty years.

As regards coppice crops in Changa Manga, the following measurements were recorded by Mr. A. Smythies in 1895 : ²

Dalbergia Sissoo : coppice measurements, Changa Manga plantation.

Age. years.	Mean height. ft.	Mean girth. ft. in.	Age. years.	Mean height. ft.	Mean girth. ft. in.
1	7.2	0 2	9	27.0	1 4.5
2	10.8	0 3.4	10	32.8	1 9.5
3	14.7	0 5	11	33.1	1 5.6
4	15.5	0 6	12	33.7	1 10.1
5	19.3	0 8.7	13	37.5	2 2.9
6	21.5	0 9.7	14	39.8	2 2.4
7	23.9	1 0.7	15	37.4	2 0
8	27.7	1 4.4			

Although statistics from the Changa Manga plantation exhibit great variation in the out-turn from different coupes, they show clearly that the yield has risen very considerably during the second rotation. This is due partly to the fact that the coupes of the first rotation consisted of seedling crops and those of the second rotation of coppice crops, and partly to the larger admixture of mulberry and the general increase in the density of the crop and the fertility of the soil during the second rotation. The revised working plan quotes the following figures illustrating this increase in the yield :

Dalbergia Sissoo : comparative yield of crops in the first and second rotations, Changa Manga.

Compartment No.	Age at felling.		Yield per acre per annum, stacked volume, thick firewood only.	
	1st rotation. years.	2nd rotation. years.	1st rotation. cub. ft.	2nd rotation. cub. ft.
Various combined	15.0	15	137	246
41	15.5	15	101	178
45	15.5	16	99	201
46	16.5	16	142	212
58	17.5	18	116	260

The following statement, compiled from details given in the revised working plan, of the out-turn in each coupe during twenty years of the second (coppice-with-standards) rotation in the Changa Manga plantation shows an approximate average obtained by plotting all coupe out-turns of different ages and constructing mean curves :

¹ Ind. Forester, xxv (1899), pp. 488-94.

² *Ibid.* xxi (1895), p. 288.

Approximate average out-turn, Changa Manga plantation, 1896-7 to 1915-16.

Age. years.	Average out-turn per acre.				Average out-turn per acre per annum.			
	Stacked volume.			Solid volume, all classes. cub. ft.	Stacked volume.			Solid volume, all classes. cub. ft.
	Thick fuel. cub. ft.	Thin fuel. cub. ft.	Total. cub. ft.		Thick fuel. cub. ft.	Thin fuel. cub. ft.	Total. cub. ft.	
<i>Sissoo and mulberry.</i>								
12	2,350	750	3,100	1,100	196	62	258	92
13	2,550	800	3,350	1,220	196	62	258	94
14	2,760	850	3,610	1,330	197	61	258	95
15	2,980	890	3,870	1,450	199	59	258	97
16	3,200	920	4,120	1,560	200	58	258	98
17	3,400	940	4,340	1,680	200	55	255	99
18	3,600	960	4,560	1,800	200	53	253	100
19	3,800	980	4,780	1,900	200	52	252	100
20	4,000	1,000	5,000	2,000	200	50	250	100
21	4,200	1,000	5,200	2,120	200	48	248	101
22	4,400	1,000	5,400	2,240	200	45	245	102
<i>Almost pure sissoo.</i>								
16	1,816	491	2,307	840	113	31	144	53

Note.—The factors now employed for conversion from stacked to solid volume are 0.43 for thick fuel and 0.12 for thin fuel.

These figures cannot be accepted as in any way representative of pure sissoo out-turns, since the great majority of the coupes probably contained a larger proportion of mulberry than of sissoo. The figures for almost pure sissoo, in the last line, represent the average of only three compartments, aggregating 340 acres.

2. *Unirrigated (including sailaba) plantations.* Some figures have been quoted above, in connexion with the development of seedlings and saplings, showing the rapid rate of growth attained by young plants even without any irrigation, provided that regular weeding and loosening of the soil is carried out; these figures show that a maximum height of nearly 14 ft. in three years has been attained under these conditions in line sowings at Dehra Dun.

The following figures show the early growth of transplants in four experimental plantations formed at Dehra Dun in 1912:

Nature of transplants.	Height at end of 3rd season (dating from year of sowing).		Percentage of survivals at end of 3rd season. per cent.
	ft. in.	ft. in.	
(1) Transplanted first rains: entire stem and roots . . .	2	0 to 10	82
(2) Transplanted first rains: entire stem and roots . . .	5	0 to 13	47
(3) Transplanted first rains: pruned stem and roots . . .	7	8 to 13	100
(4) Transplanted second rains: pruned stem and roots . . .	maximum	5 6	100

The ground was hoed up and weeded prior to transplanting, but no weeding or watering was done afterwards. Nos. (2) and (3) adjoined each other: Nos. (1) and (4) were on somewhat stiff soil.

A sample plot measured in 1918 in a plantation forty-two years old in the Gorakhpur district, United Provinces, showed a mean girth of 4 ft. 7 in., a mean height of 97 ft., and a timber volume of 1,800 cub. ft. standing and 600 cub. ft. removed in thinning.

The following figures give the results of measurements of trees and crops

in the plantations of the Thapal Grant estate, Saharanpur district, United Provinces, in 1907 :

Age. years.	Number of trees per acre.	Mean girth. ft. in.	Mean height. ft.
4	—	0 7.8	17.6
6	557	0 11.3	25.1
7	482	1 1.6	31.3
16	—	3 0.3	40.0 (average of 140 trees along sides of paths)

Measurements made by Mr. A. L. McIntire in 1885 in the Shahdera-Jugian *sailaba* plantation gave the following results :

Age. years.	Number of trees per acre (thinned crops).	Mean girth at 4 ft. from ground. ft. in.	Mean height. ft.	Mean solid volume per tree, material over 2 in. diameter. cub. ft.
10	250	1 8	40	4.34
12	250	2 3	45	5.38
14	160	2 6	45	8.40
17	150	3 0	50	11.80
18-19	Standards isolated one year previously	3 4	53	14.50

As already mentioned, the out-turn from this plantation during the first rotation of fifteen years amounted to 230 cub. ft. stacked per acre per annum including brushwood, or 200 cub. ft. excluding it.

The Jhelum *sailaba* plantations gave a girth of 4 ft. at thirty years (Gamble).

3. *Natural crops.* Statistics relating to the rate of growth and out-turn of natural sissoo crops are as yet somewhat scanty. A commencement was made by the Forest Research Institute in 1910-11 in the establishment of sample plots to be measured periodically, and these should in time furnish useful statistics. Estimates in working plans are based on ring-countings ; it is true that the rings on stumps are at times tolerably clear, but they cannot always be relied on to give accurate results. The working plan of the Ganges (now Lansdowne) forest division, United Provinces, estimates a girth increment for alluvial sissoo on the Ganges islands of 1.7 in. per annum, giving a girth of 3 ft. in twenty-one years. The Dehra Dun working plan estimates that it will take 75 and 100 years to produce trees 4½ and 6 ft. in girth respectively in the alluvial forests of the Dun. Mr. F. Gleadow (quoted by Gamble) reported measurements of nearly 900 trees in the natural forests of Oudh. which for an average age of 15½ years gave a mean girth of 35 in. and a mean height of 50 ft.

The following statement shows the results of five years' growth in girth and height in the case of three sample plots laid out by the Forest Research Institute in young alluvial crops on sand and shingle in a dry river bed at Dholkund in the Saharanpur Siwaliks, where the normal rainfall does not exceed 45 in. :

Dalbergia Sissoo : girth and height measurements in natural young crops, Siwaliks.

No.	Girth.					Height.				
	First measurement.		Remeasurement after 5 years.		Mean annual girth increment for period.	First measurement.		Remeasurement after 5 years.		Mean annual height increment for period.
	Mean.	Maxi-mum.	Mean.	Maxi-mum.		Mean.	Maxi-mum.	Mean.	Maxi-mum.	
	in.	in.	in.	in.		ft.	ft.	ft.	ft.	
1	—	7.2	7.0	11.5	0.86 ¹	10	15	24	33	3.6¹ 2.8² 1.4 0.6
2	8.6	—	11.6	—	0.6	20	—	27	—	
3	13.5	—	19.1	—	1.1	33	—	36	—	

¹ Largest stems only.

² Average of all stems.

In the moister localities the growth is probably a good deal faster : but in estimating the age of natural crops due allowance must be made for the conditions under which they have developed in early youth, since the growth may be checked for years by adverse influences such as grazing, weeds, &c. Assuming that the young plants have overcome such obstructions and have commenced their normal development, their subsequent growth is rapid up to middle age, after which it appears to slow down.

2. *Dalbergia latifolia*, Roxb. Blackwood, rosewood. Vern. *Sitsal*, Beng., Oudh ; *Shisham*, Mar. ; *Sissu*, Guz. ; *Biti*, Kan. ; *Jitengi*, Tel. ; *Itti*, Tam., Mal. ; *Thothagatti*, Tam. (Fig. 131.)

A large deciduous (nearly evergreen) tree with a full rounded crown. Bark fairly thin, grey, exfoliating in thin longitudinal flakes. The tree somewhat resembles *D. Sissoo*, but has denser and darker foliage, the leaflets being orbicular and obtuse or emarginate instead of rhomboidal or broad ovate and acuminate ; it remains in leaf longer than *D. Sissoo*. Sapwood small, yellow ; heartwood dark purple with black streaks. The wood is very hard, close grained, strong, durable and ornamental, and is used for a large number of purposes, such as furniture, panelling, ornamental work, ordnance work, agricultural implements, &c. It is exported to Europe under the name of rosewood or Bombay blackwood. It is a good shade tree for coffee. Under favourable conditions the tree reaches large dimensions. In Coorg Mr. H. Tireman has recorded girth measurements up to 15 ft. 5 in. and estimated heights up to 130 ft.

DISTRIBUTION AND HABITAT. The sub-Himalayan tract from Oudh (Gonda and Bahraich) to Sikkim, Chota Nagpur, central, western, and southern India. Although often found in considerable abundance the tree is not typically gregarious like *D. Sissoo*, but grows more or less scattered in mixed deciduous forests. Exceptionally it is found gregarious in patches on alluvial flats, as in the Dangs forests of Surat, Bombay. In the Western Ghats and in the fairly moist deciduous forests of southern India it attains large dimensions. In Bombay it occurs at various elevations up to 3,000 ft., associated with teak, *Terminalia tomentosa*, and other trees, and with bamboos, in mixed deciduous forest ; as a rule it forms only a small percentage of the crop. It reaches its best development on deep moist soil at moderate elevations. Talbot says it is indigenous in the dry savannah forests of Khandesh on trap, and that



FIG. 131. *Dalbergia latifolia*, Bombay Presidency.



FIG. 132. *Dalbergia latifolia* seedlings 5 months old.
Dehra Dun. Staff shows 1 ft.

it ascends to 3,700 ft. in the Akrani, mixed with teak, *Ougeinia dalbergioides*, and *Zizyphus Jujuba* ; here it is usually a small tree owing to the unfavourable conditions of soil and climate. In Madras it occurs in many districts, but perhaps reaches its best development on the western slopes of the Nilgiris up to 4,000 ft., and on the Anamalais up to 4,500 ft., in mixed deciduous forests associated with teak, *Terminalia tomentosa*, *T. paniculata*, *Lagerstroemia lanc olata*, *Anogeissus latifolia*, *Xylia xylocarpa*, and other trees, often with bamboos : it is most common in comparatively moist situations near streams. On the Anamalai slopes of South Coimbatore trees of very large dimensions, with a girth up to 20 ft. and a clear bole up to 70 ft., are sometimes found. It is also found in fair quantity and of large dimensions in North and South Malabar. Elsewhere in Madras it often occurs in drier types of forest, where it does not attain large dimensions. In Mysore it is found scattered in mixed deciduous forest. In Coorg it occurs chiefly in deciduous forest of the moister type up to 4,000 ft. elevation or even higher, attaining its largest size (sound trees up to 7 ft. girth and 100 ft. height) in moist localities in association with *Bambusa arundinacea*. Bourdillon says it is widely distributed in Travancore between sea-level and 4,000 ft., though less common at the lower elevations and nowhere abundant ; he says it is found in grass forest in company with teak, and sometimes in the drier parts associated with evergreen trees.

In the Central Provinces it is fairly widely distributed in mixed deciduous forests, though nowhere very abundant : its most important companions are teak, *Terminalia tomentosa*, *Lagerstroemia parviflora*, *Anogeissus latifolia*, and *Ougeinia dalbergioides*. It attains its largest dimensions (5 to 6 ft. in girth) in Chanda, but trees over 4½ ft. in girth are seldom sound. In Bihar and Orissa the tree is somewhat scattered and does not reach large dimensions ; in Chota Nagpur it is commonest on cool aspects and along streams (Haines). In the United Provinces it is sparsely scattered in the dry deciduous forests of Bundelkhand and adjacent tracts, and also along the sub-Himalayan belt in the Gonda and Bahraich districts, chiefly in mixed deciduous forest, but sometimes in sal forest ; here it reaches its northern limit, and is of small size.

The blackwood grows on a variety of geological formations, including gneiss, trap, laterite, boulder deposits, and alluvial formations, but it requires good drainage, and reaches its best development where the soil is deep and moist, particularly in the neighbourhood of perennial streams. It will grow fairly well on black cotton soil and also accommodates itself to poor dry stony soil, where, however, it does not reach large dimensions. In its natural habitat the absolute maximum shade temperature varies from 95° to 118° F., the absolute minimum from 32° to 60° F., and the normal rainfall from 30 to over 200 in.

LEAF-SHEDDING, FLOWERING, AND FRUITING. In dry localities the leaves are shed about February–March, the new leaves appearing in April–May. In moister localities the tree is seldom quite leafless. The flowering season is variously recorded. Brandis (northern and central India) says April (with the new leaves) ; Bourdillon (Travancore) says January–February ; Talbot says April–May (with the new leaves) in the drier parts of Bombay, but adds that in moist localities (Kanara) it does not flower regularly or abundantly, and as far as is known only in August ; Haines (Central Provinces and Chota

GERMINATION (Fig. 133, c-g). Epigeous. The radicle emerges from one end of the seed and curves downwards ; the hypocotyl arches and pushes its way through the valves of the indehiscent pod, which become soft when soaked. The cotyledons are carried up above ground, either leaving the testa in the pod or carrying it up and dropping it when they expand.

THE SEEDLING (Fig. 133).

Roots : primary root long, not conspicuously thickened, terete, tapering, wiry, yellow or whitish at first, turning brown : lateral roots numerous, moderately long, fine, fibrous, distributed down main root : nodules present. *Hypocotyl* distinct from root, 1-2.5 in. long, more or less quadrangular and grooved, often tapering slightly upwards, greenish white, turning green then brown, glabrous, arched during germination. *Cotyledons* : petiole up to 0.06 in. long. Lamina 0.6-0.8 in. by 0.4-0.5 in., foliaceous, somewhat fleshy, reniform, with an angular projection on the basal half of the incurved side, apex rounded, base sub-sagittate, entire, glabrous, bright green above, paler beneath, midrib distinct, depressed, lateral veins somewhat obscure. *Stem* erect, terete, wiry, zigzag at the nodes, green turning brown, glabrous ; internodes 0.3-1.3 in. long. *Leaves* alternate, compound, first two to five usually trifoliate, subsequent leaves 5-foliate, then 7-foliate, and sometimes 9-foliate in first season. Stipules 0.1-0.15 in. long, linear falcate, acute or acuminate, stipels absent. Trifoliate leaves with petiole 0.5-0.8 in. long, slender, glabrous ; leaflets very shortly petiolulate, elliptical, ovate or obovate emarginate, entire, glabrous : terminal leaflet 0.5-0.9 in. by 0.3-0.7 in., lateral leaflets opposite or sub-opposite, 0.5-0.7 in. by 0.4-0.5 in. Subsequent leaves with rachis up to 4.5 in. long ; leaflets shortly petiolulate, elliptical ovate or obovate or orbicular, sometimes emarginate, entire, glabrous ; terminal leaflet up to 1.7 by 1.3 in., lateral leaflets alternate, smaller than terminal leaflet, up to 1.6 by 1 in.

The growth of the seedling is moderate during the first year, but in the second and subsequent years it is rapid under favourable conditions. Development is greatly stimulated by weeding and watering, particularly the former when accompanied by periodical loosening of the soil. Plants raised at Dehra Dun in broadcast sowings regularly weeded but not watered showed the following maximum heights at the end of the first four seasons : (1) 1 ft. 2 in.,

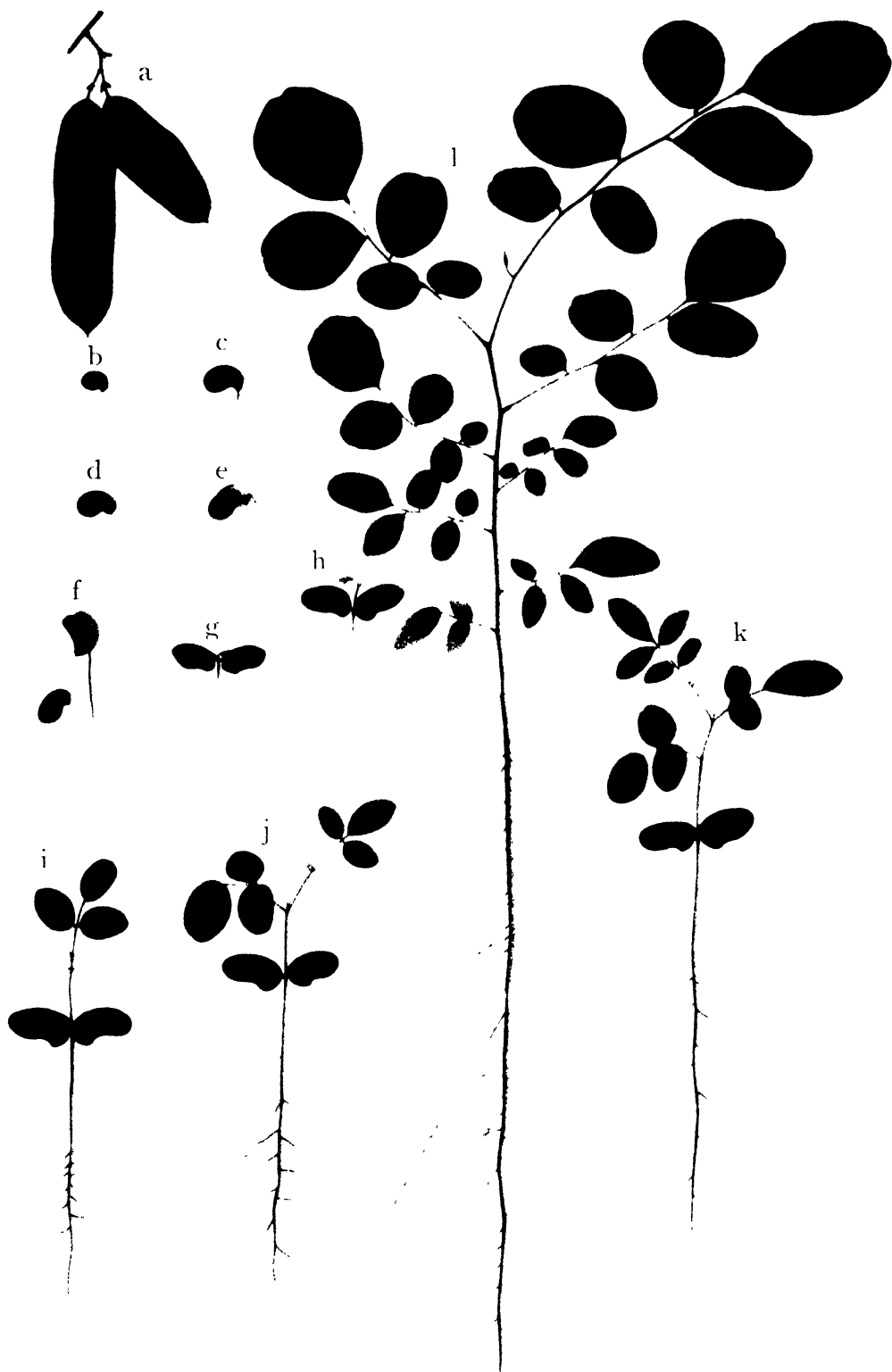


FIG. 133. *Dalbergia latifolia*—SEEDLING $\times \frac{1}{2}$

a -Fruits b -Seed c - g -Germination stages (seed extracted from pod)
 h - k Development of seedling during first season l Seedling in second season

boundary lines, and the like. Mr. S. H. Koorders¹ describes the prolific growth of root-suckers in a plantation formed in 1875-6 in the Banjumas district of Java on a low ridge on stiff reddish brown clay soil of poor quality, cracked in dry weather, with a hard pan of ironstone below the surface. The trees in sixteen years (1891) had reached a height of 49 to 72 ft.² Every tree was surrounded with a thicket of suckers, the largest of which were 30 ft. high. One tree 50 ft. high and 1 ft. 11 in. in diameter at breast height was selected for the number of suckers produced, and dug up and found to have 200 suckers up to 30 ft. high; the largest had developed a perfect root-system of its own and was throwing out horizontal roots with the view of producing new suckers. For a poor locality of the kind described the growth is so rapid as almost to give rise to a suspicion of a mistake either in the identity of the species or in the age of the plantation: the species, it is stated, was determined by Dr. J. G. Boer, Conservator of the Royal Herbarium at Leyden.

NATURAL REPRODUCTION. Under natural conditions germination takes place in the early part of the rainy season. The various factors affecting the establishment of natural reproduction by seed require further study. So far as is shown by experiments carried out hitherto, the chief cause of mortality in the germinating stages and during the early development of the seedling after germination is drought in situations exposed to a hot sun. Where the pods have been covered with earth, or are protected from the sun in open places by a moderate growth of grass or in the forest by shade which is not too dense, conditions for natural reproduction are usually favourable; the most favourable conditions are moderate shade with bare ground and loose fairly moist soil. For the subsequent development of natural saplings the best results are obtained by the plentiful admission of overhead light. Heavy bamboo cover is found to suppress the seedlings and prevent their development, while much mortality is caused by dense weed-growth. In the Madras Forest Report of 1915-16 it is stated that in East Kurnool the cutting back of the bamboos to favour tree species resulted in a profuse mass of blackwood seedlings. In forests protected from fire and grazing natural reproduction is usually good under light shade, while it is sometimes abundant on open grassy places and on ridges, though in such cases it is probable that much of the reproduction consists of root-suckers.

ARTIFICIAL REPRODUCTION. The tree can be propagated artificially from cuttings put in early in the rains, by planting root-suckers or sections of lateral roots, or from seed by direct sowing or by transplanting from the nursery. Various experiments in sowing and planting have been recorded, and it has generally been found that in dry situations drought is the chief danger to be feared; fairly good results have been obtained in some localities, particularly in the moist forests of Coorg, by sowing under partial shade in the forest on patches cleared and burnt. Sowing in *kumris* (shifting cultivation) also gives much promise. This species would appear to be a suitable one for raising as an under-story in teak plantations provided the teak is sufficiently thinned out.

Various experiments in the artificial propagation of blackwood have been carried out at Dehra Dun; the results showed that direct sowing is preferable

¹ Ind. Forester, xx (1894), p. 282.

² Dimensions, which in the original are given in metres, have been converted to feet and inches.

to transplanting, as the mortality may be considerable if dry weather follows the transplanting. In either case it is unnecessary to extract the seeds from the pods, though it is advisable to break the pods into sections, each containing one seed.

In order to raise plants for transplanting the seed should be sown in well-raised seed-beds of porous sandy loam in drills about 9 in. apart or in longitudinal lines about 18 in. apart, according as transplanting is to be done during the first or the second season. The sowing should be carried out in March or April, the beds being regularly watered and weeded and protected from the sun during the heat of the day. The seedlings may be planted out early in the first rains either with entire roots and stems or with stems pruned down to about 2 in. and taproots to about 6 in. The seedlings may be kept in the nursery till the early part of the second rains; in this case they should be thinned out during the cold season, and before transplanting the stem should be pruned down to about 2 in. and the taproot to about 12 in. Transplanting with pruned stem and roots has given better results than transplanting without pruning. Owing to the risk of mortality from drought it is always advisable where possible to water the transplants during dry weather for some time after planting.

So far as direct sowings are concerned, the great secret of success is regular weeding and loosening of the soil; excellent results have been attained in this way at Dehra Dun without any watering at all. In actual practice the best results were attained by line sowings, preferably with the aid of field crops. A spacing of about 12 ft. between lines should be sufficient, the lines being well ploughed or hoed up to a width of about 18 in. and the seed sown shortly before the commencement of the rains and lightly covered with earth. For every 100 ft. of line 5 oz. of pods should suffice. Weeding and loosening of the soil should be commenced before the weeds become dense, as it has been found that the sudden removal of heavy weed-growth from over the seedlings may cause them to die of drought.

Experiments in line sowings with field crops, the crop employed being the lesser millet or *mandwa* (*Eleusine coracana*), showed that the best results are obtained by leaving a clear strip about 2 ft. wide along the lines, the field crops being sown in the intervening spaces. If the crops are sown over the whole ground the seedlings are liable to suffer from suppression and also from the sudden exposure when the crops are reaped. Regular weeding is carried out along the lines by the cultivator, and hence if the cultivation of the crops is continued between the lines for a second season the cost of establishing the plantation is much reduced.

Experiments were carried out at Dehra Dun to ascertain if line sowings left unweeded during the rains would survive the suppression and sudden exposure if the weeds are removed after the rains. It was found that the seedlings survived well under a comparatively heavy growth of grass and weeds, and that they did not suffer from the removal of the cover provided this was carried out after the growing season was over, in the early part of the cold weather. This experiment is of importance in that it is not always possible to obtain labour for weeding in the rains, whereas weeding and soil-loosening, even if carried out only in the dry season, stimulates the development of the plants considerably.

Mr. L. S. Osmaston ¹ has described the results of experimental sowings of *Dalbergia latifolia* and other species in the Bombay Deccan, in a locality where the normal rainfall is slightly under 20 in. and the absolute maximum and minimum temperatures are 114° and 48° F. respectively. In dry localities of the kind, he found that the only successful method was by means of sowings in combination with field crops. The crops employed were sesamum, cotton, and the lesser hemp. The tree seed was sown with the agricultural sowing implements of the country. It was found more satisfactory to raise the plantations by the agency of lessees than by departmental agency. Two different methods were tried: (1) the first year the lessee was allowed to cultivate with field crops, the tree seeds as well as field crops being sown in the second year and weeding being carried out twice in the year the tree seeds were sown; one line of tree seeds was sown to three of field crops, and the lines being about 1 ft. apart the distance between the lines of tree seeds was about 4 ft.; (2) under the second method the tree seeds were sown in strips 4 ft. broad, in four lines 1 ft. apart, alternating with strips of field crops 8 ft. broad; during the second year the lessee cultivated field crops between the strips of tree seedlings and also weeded and sowed up blanks in the latter. The former of the two methods had only been recently tried, but the latter had given good results up to date, though the success of such operations must depend largely on the rainfall in any particular year. In these sowings a maximum height of 12 ft. and a maximum girth of 6 in. was attained in 3½ years. Where the work was carried out departmentally the total cost during the first three years (including collection and sowing of seed and weeding, but not including supervision) was Rs. 28-11-0 per acre; the receipts from the produce of the field crops was Rs. 32 per acre, leaving a net profit of Rs. 3-5-0 per acre.

Experiments at Dehra Dun have shown that the blackwood can be grown in irrigated plantations in the manner described for *Dalbergia Sissoo*. The blackwood, however, would probably be intended primarily for the production of timber and not of fuel, and it is not certain if the proportion and quality of the heartwood from trees grown in irrigated plantations would answer requirements.

SILVICULTURAL TREATMENT. Existing working plans usually prescribe either coppice-with-standards, in which blackwood is one of the species ordinarily reserved as standards, or else some form of selection fellings, the minimum exploitable girth being fixed as a rule at 6 ft. In either case it is usual to prescribe the artificial reproduction of the blackwood and other principal species to supplement natural reproduction where it is insufficient. Now that concentrated systems of exploitation and regeneration are gaining ground in India, the future treatment of this species will no doubt demand more intensive measures for artificial reproduction over definite areas in combination, if desired, with teak and other valuable species.

RATE OF GROWTH. The rate of growth of the blackwood under natural conditions is by no means fast. Working plans estimate that the trees reach an average girth of 6 ft. in 110 years in Kurnool and 160 years in North Kanara, while in the North Dangs of Surat a girth of 3½ ft. is estimated to be reached in 80 years. In Mysore a girth of 6 ft. is reckoned to be reached in 80 years.

¹ Ind. Forester, xxxiii (1907), p. 265.

Brandis gives 5 to 9 rings per inch of radius, corresponding to a mean annual girth increment of 0.7 to 1.26 in. Some of Gamble's specimens showed 8 rings per inch, or a mean annual girth increment of 0.78 in. He also quotes a statement by Mr. A. W. Lushington to the effect that 20 samples in Cochin territory on the Western Ghats gave an average of 3 rings per inch, indicating, as is natural, that the rate is faster in moist climates than in dry ones. A case of abnormally rapid growth in a plantation in Java has been referred to above, while figures of growth in youth have been given under 'the seedling'.

The following statement gives a summary of the results of ring-countings in the Ankola and Kalinaddi slopes forests of the North Kanara district, Bombay,¹ after converting to girth measurements, allowing for bark thickness, and constructing average curves :

Dalbergia latifolia : rate of growth in girth in high forests of the North Kanara district, Bombay.

Girth.				Girth.			
Ankola high forest.		Kalinaddi slopes.		Ankola high forest.		Kalinaddi slopes.	
Age. years.	ft. in.	ft. in.		Age. years.	ft. in.	ft. in.	
10	0 7	0 7		90	3 11	4 3	
20	1 1	1 2		100	4 3	4 7	
30	1 7	1 8		110	4 7	4 10	
40	2 0	2 2		120	4 11	5 1	
50	2 5	2 8		130	5 3	5 4	
60	2 10	3 2		140	5 6	5 7	
70	3 3	3 7		150	5 9	5 10	
80	3 7	3 11					

Bark thickness 0.2 in.

As regards coppice, measurements made in 1916 in the Saitba coppice coupes, Kolhan, Bihar and Orissa, on poor hilly ground, gave the following results :

Dalbergia latifolia : rate of growth of coppice, Saitba.

Ankola High Forest			Kalinaddi Slopes		
Age. years.	Mean height. ft.	Mean girth. in.	Age. years.	Mean height. ft.	Mean girth. in.
2	4.5	1.8	10	20.5	7.7
4	9.5	3.6	12	23.5	9.0
6	13.5	5.0	14	26.5	10.3
8	17.0	6.4			

3. *Dalbergia sissoides*, Grah. Malabar blackwood. Vern. as for *D. latifolia*, viz. *Thothagatti*, Tam. ; *Itti*, Mal.

A southern Indian tree very closely allied to *D. latifolia*, occurring in Malabar, the Palnis, Anamalais, Madura, Tinnevely, Travancore, and probably Coorg. It is a smaller tree than *D. latifolia*, with more numerous leaflets, and lighter coloured and less compact foliage : the young leaves of *D. latifolia* are dark green, while those of *D. sissoides* are pale green. Bourdillon² says the wood is readily distinguishable ; that of both species has a purple ground, but whereas that of *D. latifolia* is uniform in colour or veined with black or red lines, that of *D. sissoides* is much mixed with dark brown,

¹ Working Plans for the Ankola High Forest, Blocks xxiv and xxv, 1908, and the Kalinaddi Slopes, Block xxvi, 1908-9, R. S. Pearson.

² Ind. Forester, xxxi (1905), p. 124.

and never has any tint of red in it ; wood-cutters accordingly term the former *kar-itti* (dark blackwood) and the latter *vel-itti* (pale blackwood). Of the occurrence of the two trees in Travancore he says that speaking generally *D. latifolia* prefers the interior forests and *D. sissoides* the outer hill-slopes ; the former ascends to a greater height, but the latter has been observed up to 2,000 ft. At lower elevations *D. sissoides* predominates, but *D. latifolia* is also found, and from the abundance of small plants of the latter it may be inferred that it was at one time more common in easily accessible places than it is now. In Travancore the flowers of *D. sissoides* appear with the new leaves in January–February, and the fruit ripens from October to January. Mr. H. Tireman says that in Coorg the flowers appear in March and the fruits ripen in June (presumably this species).

4. *Dalbergia cultrata*, Grah. Burma blackwood. Vern. *Yindaik*, Burm.

A moderate-sized to large deciduous tree. Bark fairly smooth with short horizontal furrows. Heartwood black with dark purple streaks, very hard, used for ploughs, knife handles, &c. The wood is very handsome, and would be suitable for furniture and ornamental work, as in the case of the blackwood (*D. latifolia*).

DISTRIBUTION AND HABITAT. Throughout the greater part of Burma, in upper and lower mixed forests and *indaing* (dry dipterocarp) forest. It is also characteristic of certain classes of lower mixed forest approaching the savannah type ; here it is associated with *Butea frondosa*, *Anogeissus acuminata*, *Careya arborea*, *Lagerstroemia Flos-Reginae*, *L. macrocarpa*, *Stephegyne parvifolia*, *Dalbergia purpurea*, and other trees, growing in low-lying tracts covered with dense tall savannah grass. It is not a gregarious tree, but is decidedly common, occurring scattered throughout the deciduous forests ; it is a common companion of the teak both in upper and in lower mixed forest. In its natural habitat the absolute maximum shade temperature varies from 100° to 110° F., the absolute minimum from 40° to 50° F., and the normal rainfall from 40 to 100 in. or more.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The tree is leafless in the hot season, the new leaves appearing about April. The white or pale pink flowers, in small panicles, appear with the young leaves. The pods (Fig. 134, *a*, *b*) ripen in the cold season and hang some time on the trees : they are brown, flat, 1 to 4 in. by 0.4 to 0.6 in., 1- to 3-seeded. About 250–300 seeds weigh 1 oz.

GERMINATION (Fig. 134, *c–g*). Epigeous. The radicle breaks through or between the valves of the pod, the hypocotyl arches, withdrawing the cotyledons in straightening, or in the case of small pods or sections of pods the valves may be carried up over the cotyledons. The testa is usually carried up, dropping with the expansion of the cotyledon.

THE SEEDLING (Fig. 134).

Roots : primary root long, terete, tapering : lateral roots numerous, fibrous : nodules present. **Hypocotyl** distinct from root, 0.9–1.5 in. long, slightly compressed, tapering slightly upwards, green, tomentose. **Cotyledons** sub-sessile, plano-convex, somewhat fleshy, 0.4–0.45 in. by 0.2–0.25 in., reniform, the incurved margin indented, apex rounded, base sub-sagittate, entire, glabrous. **Stem** erect, terete, zigzag at the nodes, wiry, tomentose, green turning brown ; internodes 0.5–0.9 in. long. **Leaves** compound, normally imparipinnate, but early leaves occasionally paripinnate, first pair opposite

or sub-opposite, subsequent leaves alternate, early leaves with 7, rarely 5, later leaves of first season with 9 leaflets. Stipules under 0.1 in. long, lanceolate, acuminate, tomentose. Rachis 0.9–2.6 in. long, finally tomentose. Leaflets with petiolules up to 0.1 in. long, opposite in first few leaves, afterwards opposite, sub-opposite or alternate, 0.4–1.3 in. by 0.2–0.5 in., elliptical, or terminal leaflet sometimes obovate, apex acute or rounded, sometimes emarginate, mucronate, entire, bright green and glabrous above, paler and pubescent beneath, leaflets of earlier leaves smaller than those of later leaves, terminal leaflet often larger than lateral leaflets.

Little is yet known regarding the habits of the seedling, except that according to experiments carried out at Dehra Dun it appears capable of standing moderate shade, and in this respect resembles *D. latifolia* rather than *D. Sissoo*.

SILVICULTURAL CHARACTERS AND REPRODUCTION. The silvicultural characters of this tree require further study, but as far as information goes at present they resemble in the main those of *D. latifolia*, which species *D. cultrata* also appears to resemble as regards the conditions necessary for successful reproduction, both natural and artificial.

5. *Dalbergia Oliveri*, Gamble. Burma rosewood. Vern. *Tamalan*, *tabauk*, Burm.

A moderate-sized to large deciduous tree, in general appearance not unlike the Burma padauk (*Pterocarpus macrocarpus*), but the leaflets are considerably smaller. The bark is yellowish grey, much resembling that of padauk, but the blaze is greenish yellow, quickly turning brown, and no red juice is exuded as in the padauk. The largest tree I have measured, in the Katha district, Upper Burma, had a girth of 6 ft. 9 in., a total height of 80 ft., and a clear bole of 50 ft. The tree is apt to form a low crown. The heartwood is hard and close grained, usually a rich red colour, though, like the red Andaman padauk, it is liable to fade if not polished. Good coloured pieces are very handsome, and are suitable for furniture and ornamental work. In parts of Upper Burma *D. Oliveri* is known as *tamalan-ni* (red *tamalan*) to distinguish it from *tamalan-byu* (white *tamalan*), which has been identified as *D. Hemsleyi*, Prain, a tree with a strong superficial resemblance to it, but having a whitish wood of no value. The Burmans also distinguish *tamalan-wa* or yellow *tamalan*, but this has also been identified as *D. Oliveri*; the distinction probably refers to some slight variation in the colour of the heartwood.

DISTRIBUTION AND HABITAT. In Burma, from Pegu northwards, chiefly in Upper Burma. The tree is not gregarious, but is found scattered in mixed deciduous forests of a dry type, often associated with teak and bamboos. It grows usually on hilly ground in localities similar to those occupied by *Pterocarpus macrocarpus*. It also occurs in *indaing* (dry dipterocarp) forest on laterite. It extends into the dry zone of Upper Burma, for example in the southern part of the Meiktila district; here it does not attain large dimensions. In its natural habitat the absolute maximum shade temperature varies from 104° to 110° F., the absolute minimum from 40° to 45° F., and the normal rainfall from 35 to 80 in.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The tree is leafless in the early part of the hot season, the new leaves appearing in April. The panicles of white flowers appear with the new leaves. The pods (Fig. 135, *a*) ripen about February–March. They are brown, flat, 3–5 by 0.5–1 in., 1- or 2-seeded;

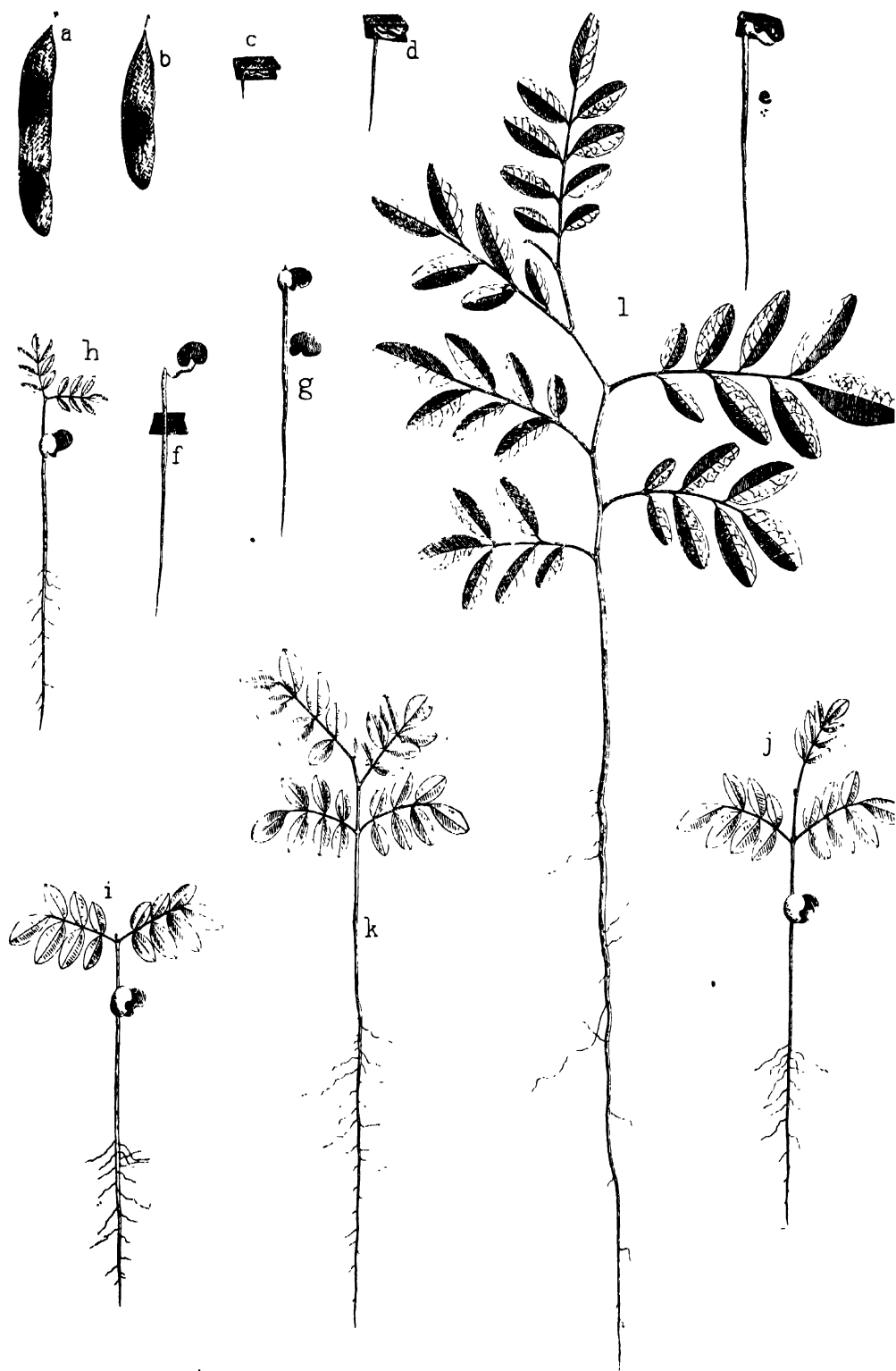


FIG. 134. *Dalbergia cultrata*. Seedling $\times \frac{1}{2}$.

a, b, fruits ; c-g, germination stages ; h-l, development of seedling to end of first season.

seeds dark brown, hard, flat, reniform, averaging 0.4 by 0.25 in., about 100 weighing 1 oz. Saplings six years old have seeded freely at Dehra Dun.

GERMINATION (Fig. 135, *b-d*). Epigeous. The radicle pushes its way through the valves of the indehiscent pod, which become soft when moistened; the hypocotyl arches and the cotyledons are withdrawn from the pod, the testa being either left in it or carried up over the cotyledons, dropping with their expansion.

THE SEEDLING (Fig. 135).

Roots: primary root long, moderately thick, terete, tapering, yellow; lateral roots moderate in number, fibrous; nodules present. **Hypocotyl** distinct from root, 1-1.2 in. long, slightly compressed, tapering upwards, white turning green. **Cotyledons**: petiole 0.05 in. long or less; lamina 0.4-0.5 in. by 0.25-0.3 in., plano-convex, somewhat fleshy, reniform with an angular projection near the base of the incurved side, apex rounded, entire, green, glabrous. **Stem** erect, terete, zigzag at the nodes, wiry, green, minutely pubescent; internodes 0.4-1 in. long. **Leaves** compound, imparipinnate, first pair opposite, subsequent leaves alternate, first few with 5 leaflets, the number increasing subsequently to about 13 leaflets by the end of the first season. Stipules 0.1-0.15 in. long, linear acuminate, pubescent; stipels absent. Rachis about 0.8 in. long in earliest leaves, increasing to about 4.5 in. in later leaves of the first season. Leaflets of early leaves usually opposite, of subsequent leaves alternate, with short petiolules up to 0.06 in. long, 0.4-1.5 in. by 0.25-0.8 in., elliptical or oblong, apex rounded or emarginate, base rounded, entire, glabrous above, minutely pubescent below; the leaflets increase in size with successive leaves.

Experiments carried out at Dehra Dun show that as regards the development of the seedling the requirements of this species agree with those of the better known species. Thus weeds are inimical to good development, which is favoured by weeding and loosening of the soil and by moderate watering; excess of moisture causes the seedlings to damp off during and after germination. With regular weeding and moderate watering seedlings at Dehra Dun reached a maximum height of about 1 ft. by the end of the first season and over 2 ft. by the end of the second season. Transplanted seedlings, which were not watered after transplanting, attained a height of 7 to 11 ft. by the end of the fourth season, including the year of sowing. A fairly long taproot is formed. At Dehra Dun seedlings shed their leaves in January, and new growth commences about March. The seedlings were found to be much subject to insect damage during and shortly after germination. They do not suffer so badly from frost as might be expected in a species growing naturally in localities where frost is unknown.

SILVICULTURAL CHARACTERS. So far as observations go at present, the silvicultural characters of this tree appear to resemble somewhat those of *D. latifolia*. During youth it stands a fair amount of shade, but requires overhead light for its best development.

NATURAL REPRODUCTION. Experiments at Dehra Dun indicate that, like other species of *Dalbergia*, the conditions necessary for successful reproduction are bare ground, loose soil, and absence of weed-growth. Under natural conditions the seed germinates early in the rains. In the mixed forests of Upper Burma in which the tree occurs, natural reproduction has usually been found to be good, young trees appearing in fair quantity under light shade, very much as in the case of *D. latifolia* in the Indian Peninsula.

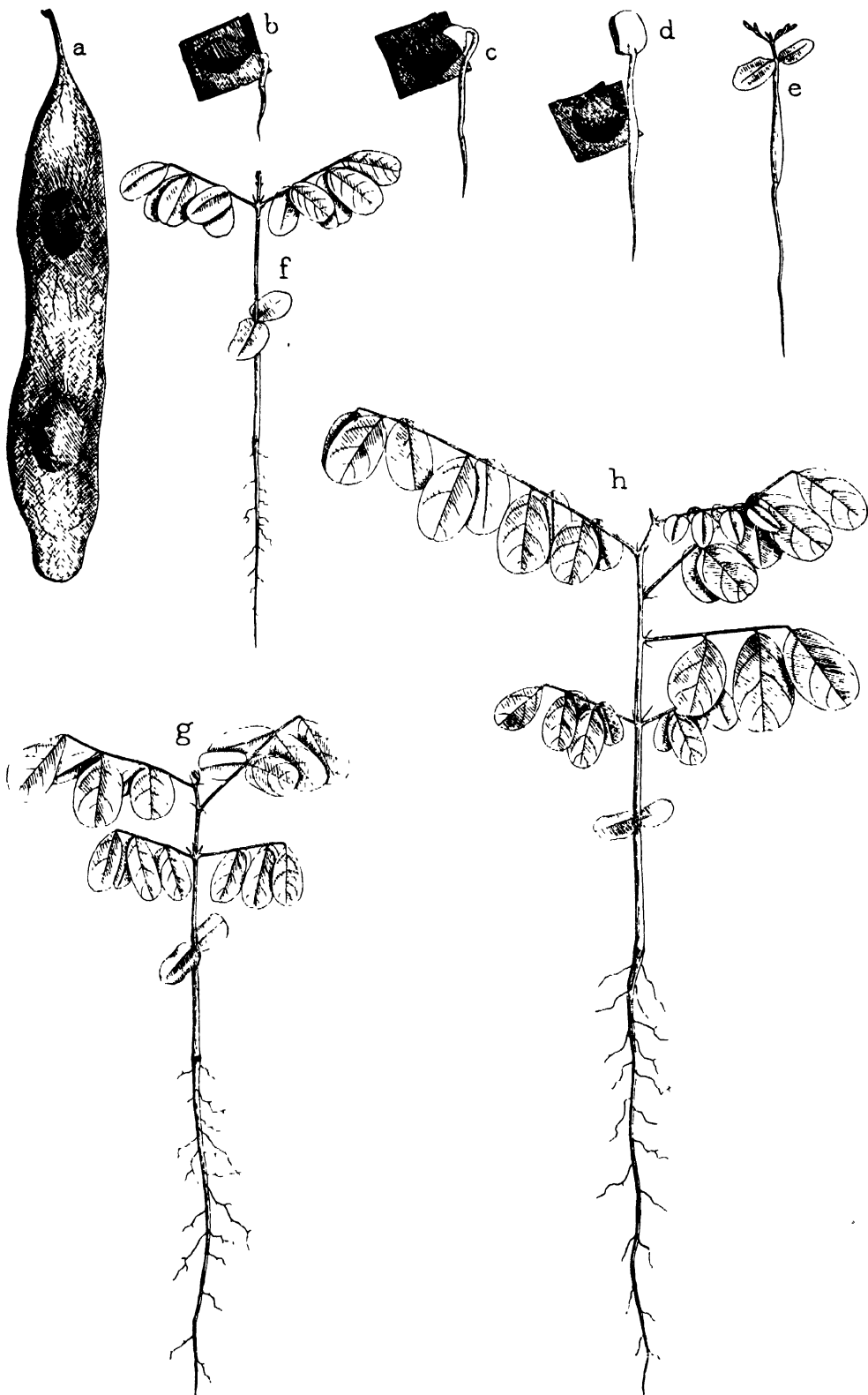


FIG. 135. *Dalbergia Oliveri*. Seedling $\times \frac{1}{2}$.
 , fruit ; b-d, germination stages ; e-h, development of seedling during first season.

ARTIFICIAL REPRODUCTION. It is probable that the best results in the way of artificial reproduction would be attained by weeded line sowings, preferably with the aid of field crops, as in the case of *D. Sissoo* and *D. latifolia*. Numbers of plants have been successfully raised in boxes at Dehra Dun, the seed being sown in April; the result was the same whether the seed was extracted from the pod or the pods were sown whole. Some of the seedlings were transplanted with entire stem and roots during the first rains, and some were left until the second rains and transplanted, some with entire stem and roots, and others with stems pruned to 2 in. and taproots to 9 in.; in each case the operation was carried out with success.

6. PONGAMIA, Vent.

Pongamia glabra, Vent. Vern. *Papar*, *kanji*, Hind.; *Karanj*, Mar.; *Honge*, Kan.; *Ponga*, Tam.; *Kanga*, Tel.; *Thinwin*, Burm.

A moderate-sized nearly evergreen tree with a spreading shady crown and short bole; bark fairly thin, smooth, grey, yellowish inside. The wood, which is yellowish white, is not durable, and is used mainly for fuel. The tree is planted for shade and ornament throughout the greater part of India. The seeds yield a thick oil used for burning and as an application for skin diseases.

DISTRIBUTION AND HABITAT. Throughout the greater part of India and Burma, chiefly along streams and rivers; common near the sea-coast in beach and tidal forests. In the Andamans it is one of the characteristic species of the mixed forests of the littoral fringe; in the Sundarbans it occurs along the sand-hills near the coast, and elsewhere along the coasts of India and Burma it is locally common. It has been largely planted, and in many places has run wild, so that it is not always easy to determine if it is locally indigenous or not.

The tree is wonderfully adaptable as regards locality; although commonly found wild in the sandy beds of streams or along the sea-shore, thriving with its roots in fresh or salt water, it is grown successfully as a roadside tree in comparatively dry parts of the Indian Peninsula or on the alluvial plains of Northern India. In localities in which it is known to have been cultivated successfully the absolute maximum shade temperature varies from 100° to 120° F., the absolute minimum from under 30° to over 60° F., and the rainfall from 20 to over 100 in.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The tree is almost evergreen, or is leafless or nearly so for a short time in May. Bourdillon says it drops its leaves several times during the year. The racemes of lilac flowers appear from April to June. The pods ripen from March to May the following year. The pods (Fig. 136, *a*) are 1.5–2 in. long by 1 in. broad, pointed at both ends, woody, indehiscent, yellowish grey when ripe, 1- or 2-seeded. The pods are easily opened by passing a knife along the suture. Seeds (Fig. 136, *b*), when solitary, 0.7–0.8 in. by 0.5–0.7 in., compressed, elliptical or reniform, wrinkled, reddish brown, testa leathery, easily cut; when there are two seeds in the pod they are flattened in contact, irregularly shaped, and angular. Tests carried out at Dehra Dun showed that the percentage of fertility is high, and that the seed retains its vitality at least a year if carefully stored.

GERMINATION (Fig. 136, *c-g*). Hypogeous. The thick radicle emerges from one end of the seed, and the primary root attains some length before

the plumule appears, the young shoot arching to extricate itself, and then straightening.

THE SEEDLING (Fig. 136).

Roots : primary root long, thick, terete, tapering, woody, whitish or light yellowish brown : lateral roots numerous, fibrous, distributed down main root : nodules present. *Hypocotyl* distinct from root, 0.4–0.5 in. long, thick, fleshy, compressed, green, glabrous, subterranean. *Cotyledons* sessile, 0.8–0.9 in. by 0.5 in., thick, fleshy, reniform, green, outer surface rounded, slightly rugose, inner flattened in contact. *Stem* erect, first internode compressed, later internodes terete, green, glabrous but young parts finely pubescent ; internodes 0.6–3 in. long. *Leaves*, first two or three often abortive ; normal leaves usually four or more simple, followed by trifoliate leaves till end of first season ; 5-foliate leaves first produced in second season. Stipules 0.1 in. long, ovate falcate. Simple leaves with petiole 0.2–1.2 in. long, terete, glabrous ; lamina 1.5–3 in. by 0.5–2.5 in., ovate acuminate, base rounded or truncate, entire, glabrous or young leaves finely pubescent. Trifoliate leaves with common petiole up to 2.5 in. long in first season, leaflets with petiolules 0.15–0.2 in. long, ovate acuminate, entire, glabrous, terminal leaflet 2.5–3.5 in. by 1.3–1.8 in., lateral leaflets opposite, somewhat smaller than terminal leaflet.

The growth of the seedling is fairly rapid. Nursery plants at Dehra Dun had a maximum height of 8 in. at the end of the first season and 4 ft. 8 in. at the end of the second season. A long stout taproot is developed at an early stage. Seedlings at Dehra Dun stand frost fairly well, the leaves being slightly touched but the stems being unaffected.

SILVICULTURAL CHARACTERS. The tree is a shade-bearer, and may be found growing naturally along watercourses under the shade of other trees. It resists drought well, having remained unaffected by the severe drought of 1899 and 1900 in the Indian Peninsula. It was badly damaged at Lahore in the abnormal frost of 1905, but ordinarily it is moderately frost-hardy. The tree produces root-suckers. It is frequently pollarded in southern India to furnish green manure. As already mentioned, it is not exacting as to locality. It grows best, however, in fairly moist situations on porous well-drained soil, thriving even on pure sand ; it will grow on black cotton soil.

ARTIFICIAL REPRODUCTION. The tree is easily raised from seed or from cuttings. The seed may be sown in the nursery when it ripens, about April or May, and the seedlings will be ready to transplant early in the rains of the next year ; in dry places the plants require to be watered regularly in dry weather for a few years. For forest purposes direct sowings in suitable localities would probably prove more successful than transplanting. In Coorg direct sowings have proved successful in the beds of streams, in which places it is a useful species to introduce.

7. ROBINIA, Linn.

Robinia Pseudacacia, Linn. Robinia, false acacia, locust tree.

A deciduous tree, with thick rough brown longitudinally furrowed bark and handsome pinnate-leaved foliage ; the young shoots are smooth, purplish brown, armed with stout triangular stipular spines in pairs, which persist for some years. In America it usually attains a height of 40 to 60 ft. with a diameter of 1 to 1½ ft., while under the most favourable conditions it may reach a height of 80 ft. and a diameter of 3 ft.¹ In Europe it attains a height

¹ U. S. For. Service Cir., No. 64.

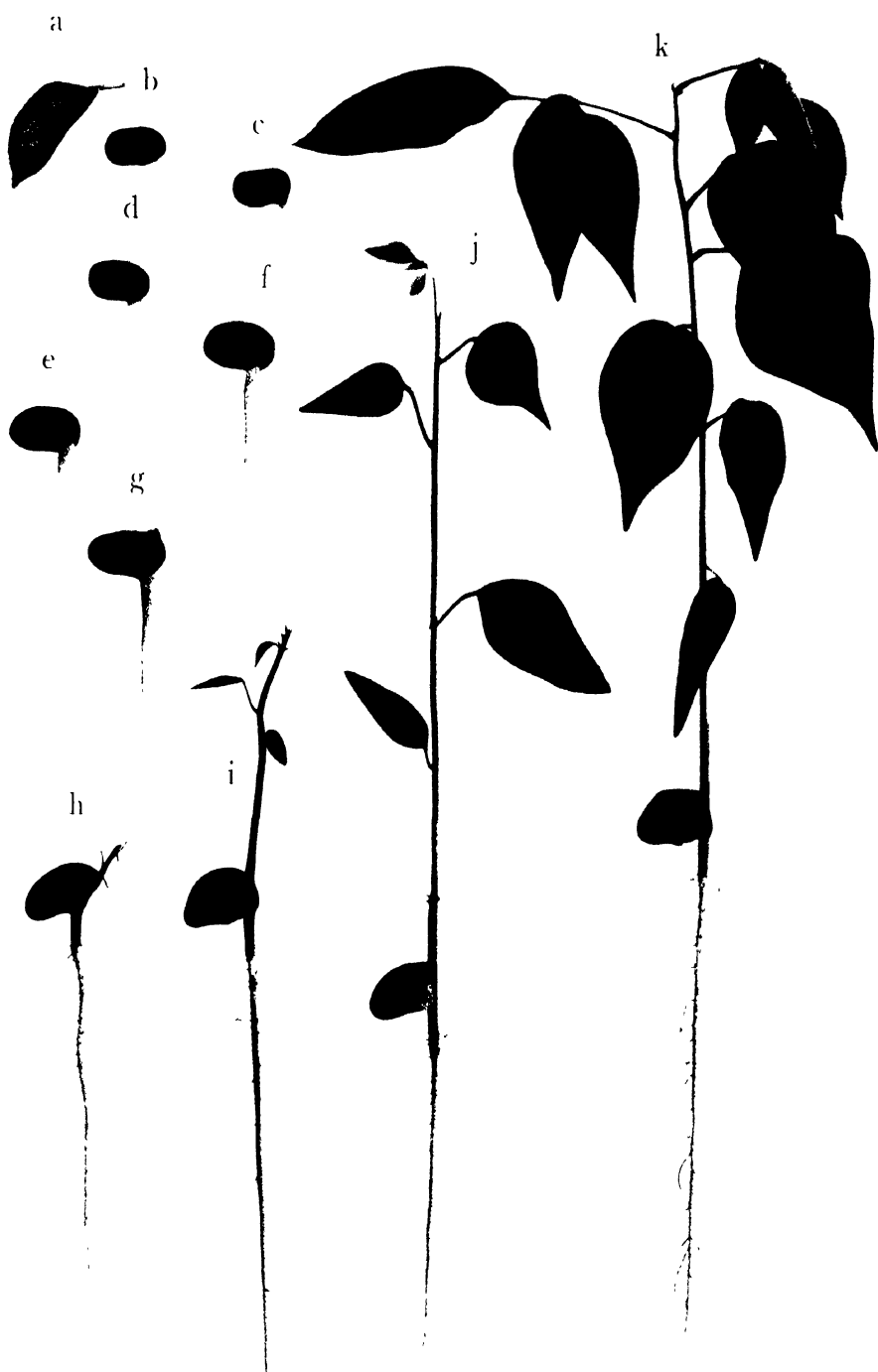


FIG. 136. *Pongamia glabra*—SEEDLING $\times \frac{3}{8}$

a—Fruit b Seed c - g—Germination stages h - k—Development of seedling to end of first season

of 80 ft. and a girth of about 15 ft.¹ The wood is hard, with yellowish brown or reddish brown heartwood : in Europe it is largely used for wheel-spokes, fence-posts, vine-props, &c. In India the tree has proved of considerable value in the Punjab Himalaya, not only as a producer of fuel but also as a useful species for clothing bare slopes and fixing unstable ground, provided the soil is deep and porous.

DISTRIBUTION AND HABITAT. The robinia is a native of North America and is indigenous in the Appalachian Mountains of the United States from Pennsylvania to Georgia, and in certain portions of eastern Indian Territory and Arkansas, but has become naturalized throughout the greater part of the United States east of the Rocky Mountains, as well as in Nova Scotia and Ontario. It has succeeded well south of the 38th parallel of latitude, thriving in regions characterized by a hot summer season : latterly, however, planting has been somewhat restricted owing to the ravages of the locust-borer (*Cyllene robiniae*, Forster), a beetle whose grubs bore into the wood. In America it is found in mixture with other trees or in pure crops on forest land that has been burnt over : it grows best on a deep well-drained fertile loam, but will grow on almost any soil except a wet heavy one ; it shows good development on limestone. Elwes² says that all his observations in England go to show that robinia is essentially a lover of a hot, dry, and sandy soil, though it attains a large size and age only on a good sandy loam, and while tolerating lime it grows much better without it. The tree was introduced into France in 1601 by J. Robin (whence its name), and has become thoroughly naturalized in that country, particularly in the Garonne and Rhone valleys, also in Hungary, Belgium, southern Russia, Italy, the southern Alps, the Balkan States, and other localities, thriving best in regions where the summer is warm : in Europe it does not grow well at high altitudes. It grows particularly well on porous soil, and in Europe is frequently grown on new embankments, spoil-banks, loose hill-sides, and taluses, and thrives on the loose sandy soil of the coastal dunes of France ; in Roumania it has proved a great success in fixing the moving sands of the Danube.

The robinia was introduced into India in the latter part of last century, and planting was commenced in the Punjab about 1890, and continued for many years at various elevations from the plains up to about 10,000 ft. It has done well at moderate elevations, that is, from 4,000 to 6,000 ft., on deep porous soil, but on dry shallow soil it has not come up to expectations as a possible species for afforesting bare slopes ; in such places it exists to some extent, but remains stunted. It avoids stiff heavy soils. Its chief value lies in fixing embankments and places liable to landslips, provided the soil is deep and porous and not too dry : its power of producing root-suckers and fixing the soil is invaluable in such places. It is now a common tree about Simla, and has also been planted to a considerable extent about Jutogh, Dagshai, Sabathu, and other places. In the Kangra valley and at Dharmsala attempts to introduce robinia have not met with success, while in the Murree hills experience has shown that it has little chance of surviving the heat and drought from April to June at elevations below 5,000 ft. It has been introduced successfully in the hills of Burma, and grows well at Maymyo (about 3,500 ft.).

¹ Elwes and Henry, *Trees of Great Britain and Ireland*, vi. 1497.

² *loc. cit.*

The climatic conditions under which the tree will thrive in India are as yet insufficiently known. At Simla the absolute maximum and minimum shade temperatures are respectively 94° and 19° F. The normal rainfall is 63 in. at Simla and 57 in. at Maymyo.

LEAF-SHEDDING, FLOWERING, AND FRUITING. In the Himalaya the leaves commence turning yellow and falling by leaflets in September. Some trees are leafless by the end of October : others are not entirely leafless until early December. The new leaves appear in the beginning of April, and by the end of that month the trees are in full leaf. The fragrant white flowers, in pendulous racemes, appear in April, at which time the trees, whose young foliage is well out, are particularly handsome, and are visited by numerous bees for the sake of the honey which they obtain from the flowers. The pods form rapidly, ripening at the end of August and during September. The pods (Himalayan) are 1–5 in. long by 0.35–0.7 in. broad, flat, brown and glabrous outside, silvery white and shining inside, containing up to 16 seeds, which are 0.2 in. long, compressed, reniform, dark brown, firmly attached to the pod valves by funicles about 0.1 in. long. Some pods commence to dehisce shortly after ripening, but dehiscence continues tardily for three or four months, being favoured by dry weather. The pods fall at various times throughout the winter and the following hot season, particularly during strong winds and storms, which blow them to some distance from the tree ; the majority of the pods remain on the trees throughout the greater part of the winter, and some remain hanging as late as the following June.

The tree produces flowers and fruits at an early age, plants three years old having been observed to produce them in the Simla hills ; small root-suckers may often be found in flower and fruit.

In places with a heavy monsoon rainfall it has difficulty in ripening its seeds.

SILVICULTURAL CHARACTERS. In its native home and in Europe the robinia is a strong light-demander : the same applies in the Himalaya, where, however, on southern slopes trees may be found persisting under light shade, though their development is impeded. In England it is liable to be broken by wind, and also suffers considerably from late and early frosts ; in France it appears to be better able to withstand frost, the young shoots becoming sufficiently lignified before the early frosts set in. In the Himalaya no serious frost damage has been noticed in the case of established trees, for although early frosts shrivel up those leaves which remain late on the trees, no real damage is done : seedlings, however, are somewhat sensitive during the first year, after which they are wonderfully hardy. At the higher elevations the tree is apt to suffer from snow-break. In France the robinia resists drought well, and has been found to be one of the most hardy species in hot dry summers. In the Himalaya it also resists drought well at elevations over 4,000–5,000 ft. ; at low elevations on hot dry slopes the seedlings die of drought, surviving only in sheltered and comparatively moist situations. The robinia coppices freely and produces root-suckers in great abundance from its superficial roots, which often attain considerable length : the root-suckers are formed at an early age, plants three years old having been observed to produce them in the Simla hills.

NATURAL REPRODUCTION. In America the pods are retained on the trees

well into the winter, and are carried long distances by the strong winter winds, and abundant reproduction often springs up on old fields or forest lands which have been burnt or cut over, resulting in many cases in pure crops: the robinia also propagates itself freely by means of root-suckers and stool-shoots, young crops killed by fire being resuscitated in this-way. In France natural reproduction by seed takes place freely only on the loosest soils, as on sand-dunes. Wherever the tree has been introduced outside its natural home it exhibits its tendency to spread by means of root-suckers.

In the Himalaya the tree preserves its original characteristic of retaining its pods well into the winter, but strong winter winds do not occur regularly as in America, and the seed is not distributed to great distances. In this region seedling reproduction has not been observed, but the tree reproduces with great freedom by root-suckers, which often form regular thickets on the hill-sides: in nurseries, also, the portions of root left in the ground when the young plants are removed send up plentiful crops of vigorous shoots.

ARTIFICIAL REPRODUCTION. The tree may be propagated by seed or by root-cuttings; stem-cuttings planted in the rains are moderately successful, but cannot always be relied on. In Europe numerous cultivated varieties and some hybrids have been produced; some of these are successfully propagated by cuttings, but grafting is usually resorted to. In America it is customary to plant out in the spring nursery-raised seedlings one year old, their height varying from 1 to 3 ft.; it has been found advisable, before sowing the seeds in the nursery, to soak them for four or five days in water heated to a temperature of 150° to 160° F., the seed then being transferred straight from the water to the seed-bed. Owing to the wide-spreading root-system close planting is avoided in America unless early thinnings can be carried out: a spacing of at least 6 ft. by 6 ft. is adopted, except in the dry climate of the middle west, where a spacing of 6 ft. by 4 ft. or 8 ft. by 3 ft. is considered more suitable.

Mr. Seurre¹ considers that a good average spacing is one of 1.25 by 2 metres, while one of 2 by 2 metres could be adopted in exceptional cases of vigorous growth on fertile ground. He adds that when plantations languish during their early years, they should be coppiced at the age of three or four years in order to obtain good and abundant shoots.

Mr. G. S. Hart² has described the method found most successful for the cultivation of the robinia in the Simla hills, and the following passage may be quoted from his note:

'Direct sowings have been tried again and again on various aspects, at different elevations, and during different seasons, but have failed completely in all cases, and so it appears certain that the plants must be raised in nurseries.

'It has been found that sowings made in the beginning of the rains were not very successful, as the amount of moisture that they then experienced was apt to kill off the seedlings: the best time then for the necessary sowings, which should be light, is from the middle of September to the middle of March, according to the altitude, and this is equivalent to saying that the seed can be sown as soon as there is no further danger to be apprehended from frost. Drainage is the main point to be seen to in the construction of the nurseries, for an excess of water, but more particularly anything in the shape of stagnant water, is fatal to the young seedlings; the nurseries should therefore be made with small raised seed-beds surrounded by small trenches, and the amount of

¹ Bull. Soc. For. Franche-Comte et Belfort, xi (March 1911), p. 14.

² Ind. Forester, xxi (1895), p. 169.

water given during the hot weather should be regulated by the appearance of the plants, care being taken to avoid any flooding of the nurseries and to see that no water remains standing in the beds. The seedlings commence germinating some three weeks after the sowings, and grow quickly, many of them attaining a height of over two feet by the break of the rains, and of over five feet by the end of the growing season, while exceptionally quick-growing specimens have been found to attain a height of eight feet six inches during this period: seedlings germinating late will naturally become more or less suppressed, but, nevertheless, it is inadvisable to attempt any rebedding during the rains, for this stops the growth of the larger and kills many of the smaller plants that are moved. Similarly to the sowings, the results of transplanting from the nurseries during the rains are not very satisfactory, and it is better to do this work during January and February, timing it so as to give the plants the benefit of the latter portion of the winter rains after they have been placed in their final situation. At first, plants of all sizes were put out into the plantations, but it was noticed that the smaller ones made very little progress during the first and sometimes also during the second year following their removal, while the large plants grew on without any such break: now, therefore, no trees under three feet six inches in height are used for transplanting, and all under these dimensions are rebedded into nurseries during January and February, and left there for another year.

'This transplanting and rebedding cannot be done without inflicting some injury on the roots, but, with the Robinia, this really does not matter; indeed, it is found that, while the transplants themselves do not suffer, the bits of the roots inadvertently left in the ground give rise to a crop of flourishing root-suckers during the following year, and these attain larger dimensions than the seedling plants.'

In the Simla hills the total cost of raising plants and putting them out comes to about Rs. 2 per 100 plants, and as the spacing adopted is usually 9 ft. by 6 ft. or 10 ft. by 6 ft. the cost per acre works out at about Rs. 15 to Rs. 16, or allowing for possible failures, say Rs. 20.

SILVICULTURAL TREATMENT. In America the tree does well in pure crops, though in the more arid regions it is considered advisable to mix with it soil-protective trees. In Europe it is usually worked as coppice often on a comparatively short rotation, and in the Himalayan plantations this method is also being followed with very successful results.

RATE OF GROWTH AND OUT-TURN. The growth of the robinia is rapid, but the tree is comparatively short-lived. In America, under favourable conditions, its average height-growth is 2 to 4 ft., and its diameter increment $\frac{1}{4}$ to $\frac{1}{2}$ in. a year; as a rule the growth slows down between the fifteenth and twentieth years, though it may continue to be rapid for about 25 to 30 years. After the fiftieth year growth almost entirely ceases.¹ Illes says that in Hungary a plantation 50 years old produced 8,800 cubic ft. of timber per acre, the trees averaging 90 ft. in height and 10 in. in diameter.² A plantation in France, 50 years old, yielded 4,300 cubic ft. per acre.³

In the Simla hills an individual tree has been known to attain a height of over 20 ft. and a girth of 1 ft. 4 in. below the first branch in three years from the sowing of the seed (G. S. Hart). The yield per acre in a plantation 25 years old at Jutogh in the Simla hills was 2,000 cubic ft. stacked.

¹ U. S. For. Serv. Cir., No. 64.

² Unwin, *Future Forest Trees*.

³ Bull. Soc. For. Franche-Comte et Belfort, x. 18.

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PRINTED IN ENGLAND
AT THE OXFORD UNIVERSITY PRESS

Goyay

**THE SILVICULTURE
OF
INDIAN TREES**

VOLUME II

Leguminosae (Caesalpinieae) to Verbenaceae

OXFORD UNIVERSITY PRESS

LONDON EDINBURGH GLASGOW NEW YORK

TORONTO MELBOURNE CAPE TOWN BOMBAY

HUMPHREY MILFORD

PUBLISHER TO THE UNIVERSITY

THE SILVICULTURE OF INDIAN TREES

BY

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VOLUME II

Leguminosae (Caesalpinieae) to Verbenaceae

PUBLISHED UNDER THE AUTHORITY OF HIS MAJESTY'S

SECRETARY OF STATE FOR INDIA IN COUNCIL

OXFORD

AT THE CLARENDON PRESS

1921

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ORDER XXIII. LEGUMINOSAE (*continued*)

SUB-ORDER II. CAESALPINIEAE

Genera 1. CAESALPINIA, Linn.; 2. POINCIANA, Linn.; 3. ACROCARPUS, W. and A.; 4. HARDWICKIA, Roxb.; 5. SARACA, Linn.; 6. AMHERSTIA, Wall.; 7. TAMARINDUS, Linn.; 8. CASSIA, Linn.; 9. BAUHINIA, Linn.

1. CAESALPINIA, Linn.

Species 1. *C. Sappan*, Linn.; 2. *C. digyna*, Rottl.; 3. *C. Coriaria*, Willd.

1. *Caesalpinia Sappan*, Linn. Sappan wood.

A small tree or shrub, the wood of which yields a red dye. It is believed to be wild in the Shan hills, and is cultivated in India and Burma.

2. *Caesalpinia digyna*, Rottl. Vern. *Sunletthè*, Burm.

A thorny scandent shrub whose pods, commercially known as tari pods, are very rich in tannin. It is found wild in many parts of Burma and Assam as well as in Bengal, occurring on waste lands and in hedgerows, chiefly near villages; it prefers well-drained ground with sandy soil and avoids badly-drained localities. The seeds are very hard and germination is difficult. Mr. I. H. Burkill¹ found that prolonged soaking had no effect, but by cutting through the outer impervious layer of the seed-coat with a minute cut germination was readily induced: Mr. W. A. Robertson informs me that in Burma germination is induced by filing through the testa. At Dehra Dun it was found that germination took place almost at once, without any harm to the seed, by soaking the seed in hot water and then removing the softened testa.

3. *Caesalpinia Coriaria*, Willd. Divi-divi, American sumach.

A small tree of the West Indies, cultivated, chiefly in southern India, for the sake of its pods, which give a valuable tanning material. It grows well in Lower Burma, bearing pods in quantity; some years ago there was a small experimental plantation at Tharrawaddy, in which the trees bore pods in abundance. It prefers well-drained ground, becoming stunted on stiff soil; in the Tharrawaddy plantation there was a marked difference where the soil became clayey.

2. POINCIANA, Linn.

Species 1. *P. regia*, Bojer; 2. *P. elata*, Linn.

1. *Poinciana regia*, Bojer. Gold mohur.

A native of Madagascar; largely grown for ornament in the warmer and moister parts of India and Burma. It is almost evergreen, and has a broad spreading crown of feathery foliage, large flaming red flowers which appear chiefly in April and May, and broad flat pods 1 to 2 ft. long, which ripen in the rainy season and remain long on the tree. It is usually grown from seed, but can also be raised from cuttings. It is fast growing, and has spreading superficial roots which kill out other plants. Its shallow root-system renders it liable to be blown down during storms.

¹ Gardens Bulletin, Fed. Malay States, vol. i, No. 6, 1913, p. 193.

2. *Poinciana elata*, Linn. White gold mohur.

A small practically evergreen tree with feathery foliage and handsome yellowish white flowers which turn orange as they fade; the flowers appear in the hot season or early rains. Wild, possibly indigenous, in the Bardé hills in Porbunder state, Kathiawar; probably not wild elsewhere in India. The tree is capable of growing on poor dry soil, and in the Bardé hills it grows in the crevices of trap and basalt rocks, where however it is stunted. It is often cultivated for ornament. It grows fast and is easily raised from seed.

3. ACROCARPUS, W. and A.

Acrocarpus fraxinifolius, Wight. Vern. *Mandania*, Nep.; *Handige, havalige*, Kan.; *Malaikonnai*, Tam.; *Balanji*, Coorg; *Yetama, mayahnin*, Burm.

A very large deciduous tree, usually with large buttresses at the base. Leaves bipinnate, with three or four pairs of pinnae each about a foot long; the young leaves are bright red. Bark thin, light grey. Heartwood light red, moderately hard, used for shingles, tea-boxes, furniture, and building. The tree is one of the largest in India. Colonel Beddome mentions that in southern India he has seen trees fully 200 ft. high and 150 ft. to the first branch;¹ he records a tree 27 ft. in girth above buttresses. Mr. Gamble states that Sir D. Brandis in his company measured a tree at Dalingkot in the Sikkim Himalaya 181 ft. high and 110 ft. to the first branch.

DISTRIBUTION AND HABITAT. The natural habitat of the tree is in the evergreen forests of the Western Ghats, chiefly on hill slopes up to 4,000 ft., Sikkim, ascending to 4,000 ft., Duars, Assam, Chittagong, and Burma. It is a tree of the regions of heavy rainfall, but Mr. Tireman mentions that in Coorg it has been cultivated for shade over coffee as far east as the 70 in. rainfall zone.

FLOWERING, FRUITING, AND SILVICULTURAL CHARACTERS. In southern India the flowers appear from November to January, when the tree is leafless. The fruits ripen from April to June. The tree is easily raised from seed, some of which germinates within a week, while some may lie dormant for as long as a year before germinating. Bourdillon notes that it reproduces well and the growth is fast. It is sensitive to frost. It is somewhat light-demanding, though capable of standing some shade in youth.

GERMINATION (Fig. 137, b-f). Epigeous. The radicle emerges from one end of the seed; the hypocotyl elongates and carries above ground the cotyledons enclosed in the testa, which soon falls off with the expansion of the cotyledons.

THE SEEDLING (Fig. 137).

Roots: primary root moderately long, terete, tapering, wiry, flexuose; lateral roots moderate in number and length, fibrous. *Hypocotyl* distinct from root, 1.1-1.8 in. long, terete or slightly compressed, glabrous or minutely pubescent in the upper part. *Cotyledons* sessile, foliaceous, somewhat fleshy, 0.4-0.7 in. by 0.3-0.4 in., elliptical or oblong, entire, glabrous, apex and base rounded. *Stem* erect, woody, yellow to rusty tomentose, particularly in the younger parts; internodes 0.2-1 in. long. *Leaves* alternate, compound, paripinnate, first 1-3 leaves with 3 pairs of leaflets, the number increasing to

¹ Ind. Forester, ii (1876), p. 196.



FIG. 137. *Acrocarpus fraxinifolius*. Seedling $\times \frac{1}{2}$.
 a, seed ; b-f, germination stages ; g, seedling six months old

6 pairs by the end of the first season. Stipules minute, yellow tomentose. Rachis 1 in. (in the earliest leaves) to 5 in. long, yellow or rusty tomentose, terminating in a fine bristle. Leaflets opposite, with petioles up to 0.05 in. long, larger towards apex than at base of leaf, those of earlier leaves 0.2–1 in. by 0.1–0.5 in., those of later leaves 0.4–2 in. by 0.2–0.8 in., ovate, acute or acuminate, base rounded or acute, entire, finely pubescent to glabrescent, lateral veins up to eight pairs.

RATE OF GROWTH. Mr. Tireman recorded in 1916 the measurements of thirty-seven young trees in an abandoned coffee estate at Mercara, Coorg. These trees were raised from seedlings about a foot high collected in the forest and planted in 1908, and at the time of measurement were therefore about eight or possibly nine years old from seed. The plants had received practically no attention since they were planted. In 1916 their height varied from 7 to 24 ft. and averaged 15 ft., while their girth varied from 4.5 to 31 in. and averaged 10.9 in.

4 HARDWICKIA, Roxb.

Species 1. *H. binata*, Roxb.; 2. *H. pinnata*, Roxb.

1. *Hardwickia binata*, Roxb. Vern. *Anjan*, Hind., Mar.; *Kamra*, *karachi*, Kan.; *Acha*, Tam.; *Yepi*, *naryepi*, *yapa*, Tel.

A moderate-sized to large tree, leafless for a short time or nearly evergreen, with graceful drooping slender branchlets and greyish green coriaceous bi-foliate leaves, the leaflets 1–2.5 in. by 0.5–1.2 in.; crown conical in early life, becoming broader afterwards. Bark of saplings almost silvery white and smooth, gradually changing as the tree gets older to dark grey and rough with irregular vertical cracks, 0.5–1 in. thick, exfoliating in narrow flakes. In isolated situations or on poor shallow soils the tree tends to branch low down and produce a short bole, but when grown in a fairly crowded crop on favourable soil it produces a long straight cylindrical bole with an elevated crown.

The dimensions vary greatly according to locality. On trap formations, characterized by a shallow and somewhat stiff soil, the tree rarely attains a height of 60 ft. and often does not reach a height of more than 30–40 ft. with a maximum girth of 3 ft. On deeper sandy soil overlying sandstone, granite and other formations it may attain a height of 80–100 ft. and a girth of 6–10 ft., with a clean cylindrical bole 40–50 ft. in length. Haines says that in the Kymore hills near the Sone river it reaches a height of 120 ft. Mr. E. D. M. Hooper records a tree with a large gnarled trunk 15 ft. in girth in the Raja's garden at Sandur, Bellary district, Madras. Almost everywhere the trees have been much mutilated by pollarding for the sake of fodder, manure, or bast fibre, and in most localities the larger trees are old pollards. Large trees are very frequently hollow, owing, it is generally held, to former damage by fire and mutilation, and possibly also to the repeated dying back in the seedling stage producing a centre of infection for subsequent decay.

The wood is perhaps the hardest and heaviest in India, the weight averaging 82 lb. per cubic foot. The sapwood is small and white, the heartwood dark reddish brown streaked with purple, close grained, very durable, used for bridge and house construction, agricultural implements, carts, wheelwork, &c. The bast yields a strong fibre largely employed for ropes, and the branches are much lopped for manure and cattle-fodder.

DISTRIBUTION AND HABITAT. The tree is distributed in isolated blocks and patches varying in extent in the drier parts of the Indian Peninsula, extending as far north as the Banda district, United Provinces. In Madras it occupies well-defined areas in the Godavari, Kistna, Kurnool, Bellary, North Arcot, Anantapur, Cuddapah, Nellore, and Salem districts. In Bombay it is fairly common in parts of Khandesh and Nasik, and is found scattered in the dry scrub forests of eastern Belgaum; Talbot says there is a small isolated patch in the Ranebennur subdivision of the Dharwar district. In the Central Provinces and Berar it occurs in parts of Buldana, Nimar, Hoshangabad, and South Chanda. In Buldana it is found in the Amdari, Geru-Matergaon, and Ghatbori reserves and intervening forests over an area of about 182 square miles. It is fairly plentiful in Nimar, and occupies restricted areas in Hoshangabad and South Chanda (south of Allapalli and in Sironcha), while it has been introduced artificially in Nagpur and elsewhere. In Chota Nagpur it is found only in Palamau, especially towards the Sone, on the other side of which, in the Kymore hills, it is frequent (Haines). It occurs locally in Mysore and in some of the Central India states, for example in Indore and Gwalior. The remarkably local distribution of the species, which is not altogether accounted for by soil and climate, is somewhat puzzling, and has not yet been satisfactorily explained.

The rock and soil on which the tree grows have a marked influence on its growth. In many localities, for example in parts of Nimar and Buldana, in Khandesh and Nasik, the underlying rock is trap and the soil is usually very shallow, soon merging into hard *murram* and thence into solid rock. On this formation it is often remarkably gregarious, forming pure crops of greater or less extent where the trees, which are frequently in the pole or sapling stage, may grow thickly together. On such ground, however, it never attains the large dimensions which it reaches on more porous soils overlying rocks which disintegrate more readily than trap. Thus the best growth is attained on sandstone, conglomerate, quartzite, granite, and schist, with an overlying soil of sandy loam or, what is a very characteristic soil for *Hardwickia*, a quartzose reddish gravelly sand. On such formations the tree frequently attains a large size, even though the overlying soil may not be deep, since the taproot has a wonderful capacity for making its way through fissures in solid rock. Here, however, it is not so characteristically gregarious as it is on trap, for although it may form pure crops it is also commonly found scattered among a miscellaneous growth of other species.

Some examples may be quoted of the occurrence of *Hardwickia binata* on shallow soil overlying trap rock. In East Khandesh, Bombay, the tree is almost pure over considerable areas, particularly on the higher ground with poor shallow soil; in places it is mixed with teak, *Anogeissus latifolia*, *Boswellia serrata*, and *Acacia Catechu*. The trees are of comparatively small size, attaining their maximum girth, about 4 ft., in the Jamner reserve: most of the trees are hollow, owing, it is believed, to former fires. In the adjoining Nasik district it occurs pure towards the Khandesh border, becoming scarcer on proceeding west until it disappears and gives place to scrub: the soil is poor and shallow and the trees are of small size. In the Nimar district of the Central Provinces *Hardwickia binata* occupies a considerable portion of the

trap areas along the branch of the Satpuras forming the watershed between the Nerbudda and the Tapti. Regarding these trap areas Mr. D. O. Witt states :¹ ' On the extreme west we find the Anjan scattered and fairly plentiful, but proceeding east it becomes less so, until we reach the railway at Mandwa, where it practically vanishes, hardly a single tree being found throughout the whole of the ridge east of the railway. Isolated Anjan are found on Samardes, and it is fairly common at the western extremity of the ridge separating Nimar from the Berar plain. It does not grow to any great size in these areas. Proceeding to the areas north of the main central ridge, we find the low and undulating hills of the Khandwa range fairly stocked with Anjan, and to the extreme west of this range, and extending almost up to the Nerbudda, we find a peculiar type of Anjan growth, viz. isolated blocks of practically pure Anjan in the pole stage, growing closely and thickly together. Old mature trees are few and far between, and where found are of small dimensions, and have invariably at some time or other in their life been pollarded. That the present pole growth is the natural regeneration of a previously existing Anjan forest goes without saying, but the manner of its formation is a subject of much speculation. . . . The average height of a mature Anjan tree throughout these areas may be put at 40 ft. and its girth at 3 ft.' Fig. 138 shows a sapling crop on trap in the Nimar district. In the Buldana district of Berar *Hardwickia binata* predominates over the greater part of the trap areas, *Boswellia serrata* being its chief companion. The forest is of poor quality, the trees having been much hacked and pollarded; the maximum height and girth of the existing trees are 25 ft. and 2 ft. respectively on the hill slopes, and 30 ft. and 3 ft. respectively on the better soil of the valleys.

Examples of the other geological formations on which *Hardwickia binata* is typically found, consisting for the most part of sandstone or metamorphic rock, occur in numerous localities. The overlying soil, as already mentioned, consists chiefly of a reddish gravelly sand or sandy loam, and although the tree is often scattered among other species, as a rule it attains much larger dimensions than it does on the stiffer soil of the trap areas. In the Kurnool district of Madras it occurs in greater or less abundance on the quartzites, sandstones, and shales of the Yerramalai hills, chiefly on reddish gravelly sand or on sandy loam, either in gregarious patches of varying extent or mixed with *Soyimida febrifuga*, *Terminalia tomentosa*, *Anogeissus latifolia*, *Albizia amara*, and teak. In some of the forests of the Cumbum range of Kurnool old trees may be found scattered amongst a thick growth of bamboos. Mr. E. M. Crothers² states that the only species with which it forms a good mixed crop is *Anogeissus latifolia*.

In the Bellary district it is found on rocky quartz soils, and in the forests of the Harpanahalli range it is probably the most numerously represented species, occurring chiefly on the more level ground at the bases of the several hill ranges; it is most abundant on the southern slopes of the Sogi reserve and at the base of the Hyarada hills, where it forms nearly pure forests.³

¹ The Sylviculture of *Hardwickia binata*, Ind. For. Records, vol. ii, pt. iii, pp. 78, 79.

² Ind. Forester, xxxi (1905), p. 380.

³ Working Plan for the Forests of the Harpanahalli Range, Bellary District, Madras, H. Tireman, 1911.



FIG. 138. *Hardwickia binata*, sapling crop on trap, Nimar, Central Provinces.



FIG. 139. *Hardwickia binata*, bushy young growth on a heavily grazed area, Nimar, Central Provinces.



FIG 140 *Hardwickia binata*, old pollarded trees on sandstone,
Nimar, Central Provinces

Here the trees consist almost entirely of pollards. In the North Arcot district it occurs on the Tirupati and other hills on gneissic rock overlain by masses of quartzite and conglomerate; the soil is usually a red loam with much sand. Here *Hardwickia* is associated with *Pterocarpus santalinus*, *P. Marsupium*, *Chloroxylon Swietenia*, *Terminalia Chebula*, *T. tomentosa*, *Albizzia Lebbek*, *A. odoratissima*, *Dalbergia latifolia*, and other species. In the Salem district it is found in the Shevaroy and Aranuttu hills on gneiss, the soil being a red ferruginous sandy loam. It occurs on rocky quartz soil in Anantapur and on the sandstones and shales of the Palnad in Kistna. In Bombay it is found on sandstone in the eastern part of the Belgaum district.

In the South Chanda district of the Central Provinces *Hardwickia binata* is prevalent on sandy and gravelly soil overlying sandstones and quartzites in the Sironcha range. Here it is essentially a tree of the sandy soils, and attains a girth of 8 ft. It avoids clay unless covered with a depth of sandy debris. In the Nimar district, apart from the trap areas already described, in which, though often remarkably gregarious, it does not attain large dimensions, there is a strip of broken and hilly ground along the Nerbudda occupied by Vindhyan sandstone, conglomerate, granite, schist, and limestone. The overlying soil is sandy or gravelly, and though as a rule by no means deep, it is porous, while the underlying rock is much fissured. On this tract, comprising the Punasa and Chandgarh ranges, *Hardwickia* is never pure, but is always mixed with other species, seldom forming more than 5 per cent. of the growing stock. The development of the individual trees, however, is here excellent, mature trees with a height of 80–100 ft., a girth of 6–10 ft., and a clean cylindrical bole of 40–50 ft. being by no means uncommon. As regards natural reproduction, a distinction has to be drawn between the forest on the hard crystalline Vindhyan sandstones, which disintegrate with difficulty and have a shallow covering of soil, and the more loose-structured conglomerates and shales, which disintegrate readily and produce a fair depth of porous soil, in that the tree regenerates as a rule more freely on the latter.

Hardwickia binata thrives in a dry climate characterized by a long period of drought, scanty to moderate rainfall, and intense heat during the hot season. In the cold season frosts occur only in certain portions of its area of distribution, particularly in low-lying places; these frosts are as a rule slight. It may be said that within its natural habitat the absolute maximum shade temperature varies from 110° to 117° F., and the absolute minimum from 34° to 50° F., while the normal rainfall varies from 10 to 60 in.; it appears to thrive best with a rainfall of 20 to 40 in.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The tree is leafless or nearly so for a short time towards the end of the cold season, the new leaves, which are tinged with red, appearing in April; in the hot weather the trees are in leaf, and their feathery foliage is conspicuous when most other species are leafless. Mr. Witt¹ draws attention to their habit of shedding branchlets: 'Towards the end of the season of growth, about March, a portion of the year's growth is shed, much in the same way as leaves are shed. . . . In April and May the ground under Anjan trees will be found to be littered with small twigs and branches, which at first sight appear to have been broken off, but

¹ *loc. cit.*, p. 101.

a closer inspection shows that they have literally been shed like leaves.' This characteristic, which is also seen in *Tamarix articulata*, *Phyllanthus Emblica*, and *Casuarina equisetifolia*, is obviously a xerophytic adaptation, and the probable explanation of the phenomenon is that the tree endeavours to protect itself from the rigours of the dry season by shedding the less completely lignified and therefore more sensitive portions of its branch-system.

The small pale yellowish green flowers, in axillary and terminal lax paniced racemes, appear from July to September, and the pods develop rapidly, reaching full size early in the cold season and ripening the following April or May. The pod (Fig. 141, *a*) is flat and samaroid, 2–3 in. by 0.4–0.6 in., oblong lanceolate, coriaceous, narrowed at both ends, with parallel longitudinal veins, containing one seed near the apex. The pod dehisces at the apex after it reaches the ground, when germination takes place. The light winged pods commence falling early in May and are often carried to some distance from the parent tree by the strong winds which are prevalent at that season : in full seed-years the ground to the leeward of the seed-bearers is often thickly strewn with pods.

The seed is exalbuminous, flat, averaging 0.8 by 0.3 in., sub-reniform, pointed at one end and rounded at the other, with a fairly hard testa. Fresh ripe seed has a high percentage of fertility, and germinates readily with moderate moisture. It is sometimes said that the seed will not retain its vitality for a year, but instances are recorded in which it has remained fertile to some extent for one or even two years. Thus, 'Yepi seed kept over from 1908 was tried in 1909 with some success', but only 20 per cent. germinated.¹ Again, Shyam Sunder Lal, Assistant Conservator of Forests, Indore state, writes :² 'We have sown one-year-old seed in the arboricultural nursery, which germinated fairly well, and the young plants were later transplanted to roadsides in Indore and are quite healthy.' Finally, in patch sowings carried out in 1912–13 in the Saugor division, Central Provinces, seed two years old and not very good germinated satisfactorily in 338 patches out of 1,200.³

The tree seeds sporadically to some extent every year, but gregarious seeding takes place on an average every three to five years according to locality. The local extent as well as the periodicity of general seedings varies, and a good seed-year in one locality need not necessarily be a good one in another. When a general seeding takes place the crop of seed is often profuse, the trees being laden with pods. The precise cause of gregarious seeding of this kind is not entirely clear, but there is a presumption, borne out to some extent by meteorological statistics, that it is induced by a season of drought the year before the seeding. The following records of seed-years are available : Nimar, 1874, 1879, 1884, 1889, 1893, 1899, 1905, 1911 ; Kurnool, 1902, 1905, 1908, 1912 ; Khandesh, 1908, 1911.

GERMINATION (Fig. 141, *b-g*). Epigeous. The apex of the pod dehisces slightly and the radicle emerges, developing rapidly into a taproot. The cotyledons expand and turn green, extricating themselves from the testa and the pod ; they remain only just above ground-level. The pod and the testa are left on the ground.

¹ Working Plan for the Yerramalais, W. Kurnool, 1913.

² Ind. Forester, xxxvii (1911), p. 65.

³ Forest Administration Report, 1912–13.

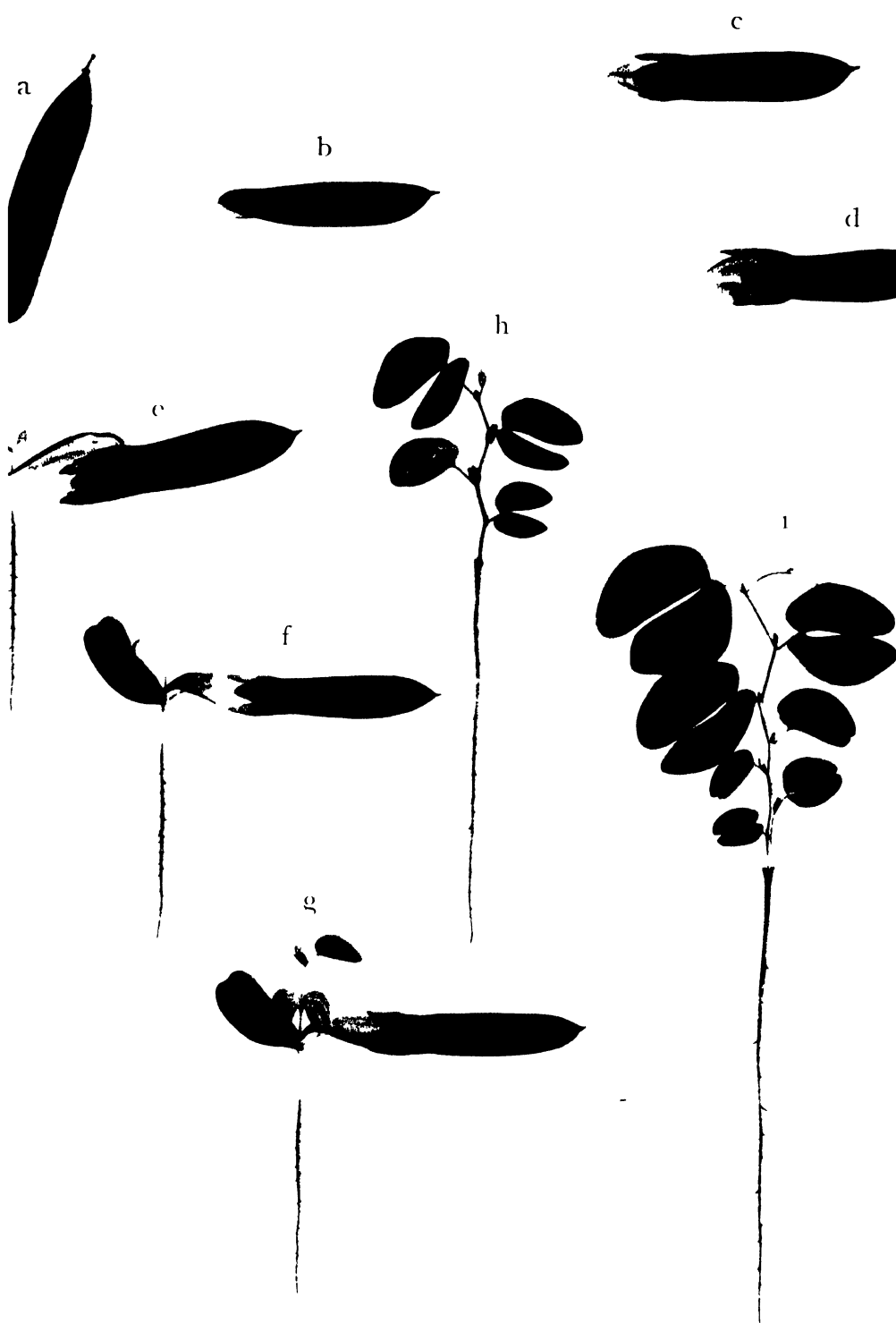


FIG. 141. *Hardwickia binata* SEEDLING $\times \frac{1}{2}$

a—Fruit b g Germination stages h i Development of seedling during first season
(Note On poor dry soil the taproot may attain a considerably greater length)

THE SEEDLING (Fig. 141).

Roots : primary root long, thin, terete, tapering, wiry : lateral roots moderate in number, short to moderately long, thin, fibrous, distributed down main root. *Hypocotyl* distinct from the root, 0.2–0.3 in. long, thick, fleshy, tapering downwards, glabrous, subterranean or at ground-level. *Cotyledons* on short thick petioles less than 0.1 in. long : lamina 1.1–1.5 in. by 0.5–0.9 in., thin, somewhat fleshy, elliptical oblong or obovate, apex broad rounded truncate or retuse, base sagittate, entire, glabrous, yellow turning green, surface irregularly depressed. *Stem* erect, terete, zigzag at the nodes, slender, wiry, glabrous, green, young parts red ; internodes 0.2–0.7 in. long. *Leaves* alternate, bifoliate, at first small, the size increasing with successive leaves. Stipules up to 0.25 in. long, ovate falcate, apex acute acuminate or rounded, pale green turning brown. Common petiole 0.2–0.6 in. long, terete, wiry, glabrous, green, that of young leaves red. Leaflets sub-sessile, 0.5–2.5 in. by 0.3–1.5 in., obliquely ovate or obscurely trapezoidal, apex rounded, base obtuse, entire, coriaceous, glabrous, darker above than below, young leaves red, arcuately 4- or 5-veined from the base.

Mr. Witt¹ has recorded the results of observations on the development of natural seedlings on a plot of ground at Khandwa in Nimar, where the normal rainfall is 30 in., and the seedlings grew on dry sandy soil 6 to 18 in. deep overlying hard *murram* soon passing into solid trap rock. These observations show that the seedlings, like those of the sal and of certain other species in dry localities, die back annually for a series of years, the taproot gradually developing until it reaches the moist layers of the subsoil and establishes itself sufficiently to produce a permanent vigorous shoot which does not die back. These observations indicate the following to be the stages of development of a normal seedling in its natural habitat :

First season. After germination, which takes place with the first heavy downpour of the monsoon proper towards the end of June, the taproot develops rapidly, attaining a length of about 5 to 6 in. within a week, the stem having two leaves almost fully formed. One month from germination the taproots of seven seedlings were dug up and found to vary from 8.38 to 16.1 in. in length : an eighth seedling had a damaged taproot 6.5 in. long. A typical seedling had four leaves fully developed and a fifth commencing to appear. There is little or no development above ground after August, the normal seedling by the end of the first season attaining a height of 5 to 6 in. with about nine leaves, while the taproot ordinarily reaches a length of 12–20 in., or even as much as 3 ft. or more if the depth of the soil permits. In this connexion 'Old Ranger'² writes : 'I have found young seedlings, of 6–9 months growth and only 3–4 in. high, the possessors of taproots 22–28 in. long (actual measurements), the almost complete absence of side shoots being very noticeable.'

The taproot shows wonderful power of penetrating hard ground and piercing what appears to be almost solid rock ; on shallow soil it twists and turns in search of fissures. By the middle of October the seedlings commence to die back, and by the middle of March, or February in dry seasons, not a single green seedling is to be found, the stems all having died back partially or completely though the taproots remain alive.

Second season. With the following rainy season the seedlings come into

¹ *loc. cit.*, pp. 89–100.

² *Ind. Forester*, xxxi (1905), p. 698.

life again, sending up new shoots from dormant buds at the points marking the axils of the cotyledons or from buds on the main stem if the latter has not been completely killed. The second year's shoot is even smaller or more weakly than that of the first year, the plant's energies being concentrated on developing its root-system. On shallow soil the taproot does not develop greatly in length, but thickens somewhat, and there is a marked diminution in the number of lateral roots. Dying back occurs again at the end of the second season.

Third and subsequent seasons. In the third season a new shoot is produced from the root-collum, neither larger nor more vigorous than that of the second season. Meanwhile the taproot develops slowly in length and thickens considerably. The annual dying back of the stem and gradual development of the taproot continues year after year for an unknown period, which Mr. Witt estimates at not less than ten years, the portion above ground gradually developing into a many-branched bush 12-18 in. high. A marked change then takes place: dying back ceases, and a leading shoot forms and grows up at the rate of about 1 ft. or more annually. By this time the seedling may be said to have reached the sapling stage, and the taproot has now become much thickened, with a length up to about 8 ft., the length varying with the depth of the soil: in shallow rocky soil the taproot is much twisted. At the commencement of the sapling stage a natural plant, especially in areas subject to grazing, usually consists of a bushy and many-branched base, from the centre of which rises the leading shoot. As the sapling increases in height the bushy growth at its base gradually dies off, and by the time the plant is 10 ft. high it has disappeared altogether. Each year's growth in the sapling is marked by slightly raised annular marks. These are due to the fact, already noted, that a portion of each year's shoot is shed at the end of each season; a scar is thus formed on the surface of which develops a bud which produces the following year's shoot. The annular marks represent the scars formed in this way.

The phenomenon of dying back on the part of natural seedlings has been recorded by previous observers in other localities. Thus Mr. E. D. M. Hooper, writing in 1903, mentions its habitual occurrence in the dry districts of Madras where the tree grows, and attributes it partly to fire and partly to the excessive heat of the dry season, and he mentions also the bushy form of growth which this dying back produces until a definite leading shoot is formed.¹ Mr. L. S. Osmaston² estimates the period of dying back at four to seven years in West Khandesh.

The phenomenon of dying back, however, is not necessarily universal, for under favourable conditions the seedling may shoot up without any check. Thus Mr. Hooper observes that occasionally under favourable circumstances a patch of young seedlings from its earliest life grows without hindrance, and notes having seen a plant grown on prepared soil at Nagpur on a trap ridge which in one season was over 5 ft. in height. Again, in patch sowings of 1911 in the Saugor district, Central Provinces, some of the seedlings are reported to have reached a height of 3 ft. in three years. Nursery plants at Dehra Dun, kept weeded and watered, reached a height of 6 to 14 in. by the end of

¹ Ind. Forester, xxxi (1905), p. 104.

² Ibid., xxxv (1909), p. 381.

the first season and a maximum height of 2 ft. 6 in. by the end of the second season, no dying back having taken place. It follows, therefore, that the habit of dying back is not innate in the species, any more than it is in the sal, teak, and many other species which die back under conditions sufficiently far removed from the optimum.

In other respects also it will be interesting to compare the habits and requirements of the seedling in its natural habitat, as observed by Mr. Witt in Nimar, with those which have been observed in twenty-one experimental plots at Dehra Dun, where, however, the climatic conditions are very different from those prevailing in the natural habitat of the tree, the normal rainfall being 85 in. and frost being at times severe. It goes without saying that for practical purposes a study of the habits and requirements of the seedling in its natural home is of infinitely greater importance than if these are observed under very different conditions, but the results obtained in the latter case are certainly interesting, for though in some respects they differ from Mr. Witt's observations, as might be expected, in others they corroborate them. The conclusions regarding the habits and requirements of the seedling, based on observations made under various conditions, may be summarized as follows :

Root-system. The development of the taproot under natural conditions has already been described. At Dehra Dun the root-system showed a tendency to strong development, even where regular watering was carried out ; this development extended to the lateral roots and was not confined to the taproot as in the case of natural seedlings. By the middle of the second season nursery plants had taproots up to 2 ft. 6 in. in length and 0.7 in. in diameter, with lateral roots up to 1 ft. 7 in. in length.

Drought. In the natural habitat of the species the seedlings are very sensitive to drought, as has already been explained in describing the phenomenon of dying back. This fact has been corroborated again and again by different observers, and it may be said without question that the great mortality noticeable among the numerous seedlings which appear after a good seed-year is due to drought, the excessive heat combined with desiccating winds producing a degree of transpiration which the root-system in the parched soil cannot make good. Even at Dehra Dun many seedlings were found to die down partially or wholly in sunny situations from April onwards.

Frost. In the natural habitat of the tree frosts are not severe enough to do the seedlings any harm, and Mr. Witt notes that he has never observed a single case of a seedling having been damaged in the slightest degree by this agency. At Dehra Dun the frost was found to be severe enough to kill back seedlings of the first year either partially or down to ground-level ; they had good power of recovery, however, and invariably produced new shoots. From the second year onwards they proved to be immune from injury by ordinary frosts.

Shape and development. The shape and development of the seedling under natural conditions has already been described. At Dehra Dun some of the seedlings commenced branching in the first year, while those which had been affected by frost or drought assumed a bushy growth in the second season, with long and rather straggling branches. Growth continued until December, all the leaves had dropped by the end of February, and the new shoots appeared

in March. The young leaves were reddish in sunny situations, and usually green in shady situations.

Damp. At Dehra Dun seedlings proved to be very sensitive to damp, numbers rotting off during the first season even in open nursery beds where watering was done too freely; in the shade hardly a single seedling survived the damp of the rainy season. This corroborates the statement of 'Old Ranger',¹ who writes: 'So sensitive are the *very* young seedlings to excessive moisture that, if seed be sown in a pot containing leaf mould or rich soil, and this be allowed to get a little too damp, the thick fleshy cotyledons of the young seedlings are immediately attacked by rot, which extends downwards to the roots, and a whole pot of young seedlings may thus be destroyed in a single night.'

Effect of grass and weeds. Various opinions have been recorded from time to time as to the effect of a soil-covering of grass on the development of the seedling. According to one theory, the extensive mortality among natural seedlings is due to the inability of the taproots to penetrate the matted roots of the grass. This explanation can hardly be accepted universally, as the degree of obstruction caused by the grass roots must vary, while the roots of *Hardwickia* seedlings have considerable power of penetrating obstructions. The effect of a matted growth of grass roots in preventing soil-aeration, however, may be of importance, and will be considered below under 'natural reproduction'. There is little reason to doubt that the development of the seedlings may be hindered or even entirely prevented from this cause, but on the other hand Mr. Witt² has proved by means of experimental plots that the very existence of the seedlings in their natural habitat may depend largely on the protection from the heat of the sun which is afforded them by a soil-covering of grass. His conclusions are summarized as follows:

(1) Grass, as such, does not hinder germination; (2) seedlings may fail to survive on soil quite free of grass; (3) the taproot is quite capable of penetrating through any obstruction of grass roots; (4) the first season of growth is the crucial one in the life-history of the seedling, the mortality being then heaviest; (5) seedlings on soil clothed with grass retain their leaves for a longer period than those on soil not so clothed; (6) the shoots of seedlings protected by a long growth of grass do not dry up so early as those from around which (though on precisely similar soil) the protecting grass covering has been cut away; (7) seedlings up to an age of $3\frac{1}{2}$ years are not smothered and killed by a dense growth of grass weighing down on them; (8) the removal of a covering of grass, from seedlings which have developed under its protection, may be distinctly harmful.

In the damper climate of Dehra Dun, on richer soil with a more luxuriant covering of grass and weeds, experimental plots demonstrated that such a soil-covering not only has a very deleterious effect on the development of the seedling, but is the cause of much mortality through suppression and through the damping off of the seedlings in the rains. These plots also showed clearly that regular weeding has a most beneficial effect on the development and survival of seedlings provided the weeding is carried out from the commencement; on the other hand, the sudden removal of grass and weeds from

¹ Ind. Forester, xxxi (1905), p. 697.

² *loc. cit.*, pp. 121-6.

around seedlings which have grown under them is very liable to cause the death of the seedlings through desiccation.

The following particulars of seedlings grown under different conditions in experimental plots at Dehra Dun demonstrate clearly the beneficial effects of regular weeding :

Hardwickia binata : measurements of seedlings in experimental plots,
Dehra Dun.

No.	Condition under which grown.	Height of seedlings at end of season.		Remarks.
		1st season.	2nd season.	
1	In nursery beds, watered and weeded	0 ft. 6 in.- 1 ft. 2 in.	Maximum 2 ft. 6 in.	
2	Broadcast sowing, irrigated, weeded	Maximum 0 ft. 10 in. ¹	0 ft. 11 in.- 2 ft. 4 in. ²	¹ 42 survivors, vigorous. ² 36 survivors, vigorous.
3	Broadcast sowing, irrigated, unweeded	Maximum 0 ft. 4 in. ³	0 ft. 3 in. and 0 ft. 4 in. ⁴	³ 8 survivors. ⁴ 2 survivors ; rest killed by suppression of grass and weeds 1½ ft. high.
4	Broadcast sowing, un-irrigated, weeded.	—	0 ft. 7 in.- 2 ft. 0 in. ⁵	⁵ 20 survivors, vigorous.
5	Broadcast sowing, un-irrigated, unweeded	—	0 ft. 3 in.- 0 ft. 4 in. ⁶	⁶ 4 survivors in poor condition ; rest killed by suppression of grass and weeds.

The observations recorded in Nimar and at Dehra Dun lead to the general conclusion that if moisture conditions are such as to prevent mortality by drought, freedom from grass and weeds, with the attendant loosening of the soil during weeding, is of great benefit as regards the development and survival of the seedling ; but where, as is probably the case in most if not all parts of the natural region of the tree, such moisture conditions do not exist, a soil-covering of grass is of benefit and may be essential for the survival of the seedling, in that it protects it from desiccation. In the latter case, however, it may be presumed, on general principles as well as from the results of the Dehra Dun experiments and of sowings in the Central Provinces and Berar, that the soil-covering of grass must have an adverse effect on the development of the seedling, and that on soil which is loosened and thus aerated better development may be expected, provided the seedling and the soil can be afforded protection by trees, bushes, or otherwise, from the desiccating effects of the sun and dry winds. This question closely concerns the natural reproduction of the species, and will be further alluded to below.

SILVICULTURAL CHARACTERS. The physical conditions under which *Hardwickia binata* grows in its natural habitat have been dealt with in some detail under distribution and habitat. It may be said in general that the tree thrives in a dry climate and is capable of establishing itself and growing on dry shallow soil and rocky ground where most other species would succumb. This is due partly to the great development of the taproot during youth and its power of penetrating hard soil and fissures in solid rock, the stem usually dying back annually during the development of the taproot, and partly to the fact that the tree stands mutilation better than the majority of species. These facts

no doubt account in large measure for its gregariousness under adverse physical conditions and its survival in spite of continuous maltreatment. The best development is secured as a rule on geological formations such as sandstone, gneiss, conglomerate, &c., which disintegrate into a porous sandy loam, rather than on the stiff and usually shallow soil overlying trap; on the latter formation, however, although development is poorer than on the former, gregariousness is more pronounced.

The great development of the taproot is maintained throughout the life of the tree, as may be observed where the root-system is exposed by scouring along the high banks of streams or the sides of ravines. On shallow soil with compact underlying rock the taproot may assume a gnarled and twisted form, running for some distance horizontally not far below the surface; in such cases the trees are liable to be blown over in high winds.

The tree is capable of standing a certain amount of shade in youth, and even requires shelter in its young stages; later it may be classed as a moderate light-demander or partial shade-bearer, though Mr. Witt states:¹ 'Even the moderate shade afforded by a mature tree of *Boswellia serrata* is too dense for an Anjan sapling to penetrate through, if once dominated. The very flexible yielding shoot of an Anjan sapling may also account to some extent for its inability to pierce overhead cover.' Mr. L. S. Osmaston² classes the tree as a partial shade-bearer.

In its natural habitat it is frost-hardy in all stages, being quite unaffected by all ordinary frosts. Except in the seedling stage it is capable of standing great heat and drought. 'This', says Mr. Witt,³ 'was very noticeable in Nimar during the droughts of 1901 and 1904. Whereas following these droughts such species as *Tectona grandis*, *Terminalia tomentosa*, *Lagerstroemia parviflora*, *Mangifera indica*, and *Buchanania latifolia* suffered severely all over the division, not only coppice being affected but also mature trees, in the case of Anjan no damage whatever was done, even on the driest soils.' The young shoots are sensitive to fire, but the power of recovery is good; ordinarily, seedlings when burnt back send up new shoots from the root-collum, but in severe fires they may be killed outright. Young plants and coppice-shoots suffer much from grazing, the leaves being browsed by deer as well as by cattle and goats; buffaloes especially are partial to them. A grazing incidence which hardly affects a teak forest will prevent young *Hardwickia* plants from making any headway. In heavily grazed areas the plants assume a characteristic bushy form (see Fig. 139).

The tree pollards well even up to a comparatively advanced age, and old pollards when re-pollarded almost invariably produce abundant new shoots: indeed, a special feature of the existing *Hardwickia* forests is the large number of pollarded trees, the result of lopping for fodder and manure (see Fig. 140). On the other hand, the tree coppices indifferently. Old trees which send out vigorous pollard-shoots if cut a few feet above the ground produce no coppice-shoots if cut flush with the ground: old pollards when felled at ground-level never coppice. In some localities a moderate amount of success has been attained by felling at 12 to 18 in. from ground-level.

¹ *loc. cit.*, p. 85.

² *Ind. Forester*, xxxv (1909), p. 380.

³ *loc. cit.*, p. 91.

Shyam Sunder Lal,¹ writing of coppice coupes in Indore state, notes that stumps of trees felled about 1 ft. from ground-level delayed sending out shoots for several months, a second inspection revealing a larger percentage of success than one made shortly after the felling.

As regards actual statistics, experiments in North Khandesh in 1903 showed that 47 per cent. of felled trees yielded coppice-shoots, the number being two to six shoots per stool and the average height in the first season being 4 ft. The most complete statistics so far recorded, however, are those published by Mr. L. S. Osmaston² giving measurements of 877 stumps in fourteen coupes in West Khandesh. The measurements included stumps of varying dimensions from under 2 ft. to over 6 ft. in girth, and of varying heights from under 2 in. to over 12 in. from ground-level: they also embraced coupes felled in years of deficient as well as of ample rainfall.

These measurements gave the following results, which are somewhat surprising:

(1) The height of the stump had no relation to its vitality: actually the percentage of live stumps of each girth class varied from 39 to 50 and averaged 47.

(2) Similarly the girth of the stump had no relation to its vitality: the percentage of live stumps of each girth class varied from 41 to 49 and averaged 47.

(3) The rainfall had no effect on the vitality of the stump, the percentage of live stumps being 53 in the case of years of most deficient rainfall and 54 in the case of years of most ample rainfall.

These results confirm the opinion generally held that coppice reproduction cannot be relied on to a sufficient extent.

Mr. H. W. Starte has recorded the result of an experiment in coppicing 10 acres of pure *Hardwickia* forest in North Khandesh. Out of 886 stumps varying in girth from 12 to 70 in., cut flush with the ground, the number which failed to coppice was 201, or 22.4 per cent.; there was no relation between girth and coppicing power.

The tree reproduces from root-suckers.

NATURAL REPRODUCTION. As already mentioned, the light winged pods ripen in April and May and fall in the latter month, being often carried to some distance from the trees; in good seed-years they are plentifully scattered over the ground. Germination takes place soon after, with the first heavy downpour of the monsoon, and seedlings may be found in quantity during the rainy season. From October onwards, however, the seedlings die off in large numbers, this mortality being due to drought: under favourable conditions it may consist of dying back with subsequent recovery, but where the seedlings have not had the advantage of protection from the hot sun they may be permanently killed off in large quantities and the seed-crop may result in complete failure. Assuming, however, that a certain number survive, their establishment and further progress until they reach the sapling stage is a matter of time owing to the annual process of dying back described above. A good deal of evidence is available regarding the factors which assist or retard natural

¹ Ind. Forester, xxxvii (1911), p. 63.

² *Ibid.*, xxvii (1910), p. 356.

reproduction, but in some respects this evidence is very conflicting, and it will be well therefore to examine it under the following heads :

(1) Effect of grass and weeds ; (2) Fire and grazing ; (3) Soil conditions ; (4) Protective shade ; (5) Climatic factors.

1. *The effect of grass and weeds* on the development of the seedling has already been discussed at some length, and it may be concluded that whereas in dry regions a soil-covering of grass assists materially in and may be essential for the establishment of natural reproduction, on the other hand where the grass is too luxuriant it may cause the death of the seedlings through suppression or through rotting off. The beneficial effects of a covering of grass in dry localities have been proved conclusively by Mr. Witt's experiments in Nimar, while Mr. L. S. Osmaston¹ says of seedlings in Khandesh that they do not mind grass even if it be 2 or 3 ft. high. Again, in Anantapur natural reproduction is reported to be good in open grassy areas.² Mr. H. F. Arbuthnot,³ writing of the Malahanagadi block, Bellary, says : ' This block is an interesting one, as it has been under special protection from grazing, cutting, and fires for the last twenty-five years. The result has been that most of the area, which was then presumably blank, has been stocked with *Hardwickia binata*, which is the principal species of the block.' Other instances might be quoted of the beneficial effects of a protective soil-covering of grass, but these will suffice.

On the other hand, there is much evidence regarding the adverse effects of such a soil-covering. Thus Mr. J. Dodgson⁴ writes : ' On account of the seed of the Anjan being so light it has great difficulty in reaching the soil through the matted growth of grass, &c., and in this way much of the seed-crop is wasted.' This accords entirely with my own observations in the case of other winged fruits (e.g. *Pterocarpus* spp.). As regards the suppression of those seedlings which do succeed in passing the germinating stage, Mr. S. Srinivasulu Naidu⁵ remarks that the heavy grass undergrowth which is common on the trap areas in Buldana probably accounts for the failure of seedlings to establish themselves owing to the smothering action of this growth. A very definite opinion on this point is expressed in the following extract from a report by Mr. L. K. Martin, quoted in the Berar Forest Report for 1903-4 :⁶

' The Anjan seeded very fairly profusely in the spring of 1902, and the seed germinated freely during the following monsoon along the Ajanta Hills, especially in the Geru-Matargaon Range around Botha and Matargaon. A very noticeable feature was the complete absence of seedlings from the midst of dense grass, that is, from areas entirely closed to grazing. They appeared wherever the grass was light, and increased in numbers with decrease in density of the grass, till over areas free of grass the seedlings were quite dense.

' The above was most noticeable round Matargaon. There in one and the same ravine the climatic factors are presumably everywhere identical, and the fertility of the soil can hardly vary much over localities only a mile apart

¹ Ind. Forester, xxxv (1909), p. 380.

² Madras Forest Report, 1913-14.

³ Ind. Forester, xxx (1904), p. 123.

⁴ Working Plan for the Anjan and Scrub Jungles of the Malegaon, Baglan, Kalvan, and Chandwad Ranges of the Nasik District, Bombay, 1906.

⁵ Working Plan of the Buldana Forest Division, Berar.

⁶ Cf. Ind. Forester, xxxi (1905), p. 105.

(at any rate they appear to me to be similar). In the portions of the reserve closed to grazing, and consequently covered with a dense crop of grass, anjan seedlings were completely absent, except just along roadsides, whereas in Survey Numbers 1, 2, 3, and 6 of Chinchkhher, which were open to heavy grazing and, being situated close to a public road, were much resorted to by cattle and as a result absolutely clean grazed, thousands of seedlings have sprung up and stand out uninjured and perfectly healthy. The above appears to prove conclusively that a dense growth of grass is inimical to the successful reproduction of anjan. The seedlings observed in those Survey Numbers have survived the past two hot weathers and escaped injury from cattle during the same period, when in the absence of other fodder cattle might have been expected to browse them off; grazing throughout the year must obviously be looked upon as a distinct advantage, in fact a real necessity.'

In addition the Dehra Dun experiments described under 'the seedling' above afford conclusive proof that where the rankness of the grass is sufficient heavy mortality may be caused through the damping off of seedlings during the rains: it should be remembered, however, that these possibly represent an extreme case of moisture seldom, if ever, met with in the natural habitat of the tree.

So far as the evidence goes, it may thus be concluded that whereas a soil-covering of grass as a protection against the heat of the sun may be an invaluable factor in the establishment of natural reproduction, under certain conditions it may become noxious, preventing the germination of seed and the establishment of seedlings owing to its rank growth; the precise conditions under which its influence is beneficial or the reverse have not yet been determined.

2. *Fire and grazing.* The direct effects of fire and grazing are, with good reason, generally held to be highly prejudicial to natural reproduction, for although the power of recovery of the seedling from injury from these causes is higher than that of many other species, great damage is suffered in unprotected areas, and reproduction is much retarded. Much evidence has been recorded in proof of this, and it will suffice to quote only a few instances. Mr. G. S. Hart¹ notes regarding Nimar: 'At present the number of Anjan seed-bearers in these forests is often small, but the natural regeneration of this species in all closed areas is excellent and is not confined, as in the Buldana district, to small seedlings, the majority of which cannot be considered as established.' Of the same forests Mr. C. F. Bell² writes: 'The hot weather kills out a large percentage of seedlings and over-grazing in the open coupes and grazing blocks completes the destruction. In coupes worked over and then closed to grazing for ten years, however, a fair number of seedlings have established themselves, and the future prospects of the crop are promising.' Again, Talbot³ states: 'Owing to sheep and cattle grazing, reproduction by seedlings over large areas in Khandesh and Nasik is much impeded. Multiplication of the species by root-suckers is, however, general and there appears little danger of the valuable Anjan disappearing from any of the areas of its distribution.' Finally, Mr. J. Tapp⁴ writes regarding West Kurnool: 'Natural

¹ Inspection Note on the Nimar Forest Division, 1911.

² Working Plan for the Reserved Forests of the Nimar District, Central Provinces, 1913.

³ Forest Flora of the Bombay Presidency and Sind, i. 457.

⁴ Working Plan for the Yerramalais, West Kurnool, 1913.

reproduction has hitherto been very poor, but since lopping of Yepi trees for fibre has been put a stop to and fire protection introduced natural seedlings of Yepi are beginning to come up in many of the reserves.'

On the other hand, instances may be quoted where fire and grazing have not had the adverse effects which they might be expected to have. Mr. Martin's report, just quoted in connexion with the effects of grass, would indicate that where there is a sufficient supply of palatable grass the seedlings may escape injury, and even benefit by the partial removal of the grassy covering; without further evidence of a similar nature, however, it would be unsafe to generalize on the results of this particular case. The same may be said of the results attained by Mr. H. L. Newman in experimental plots in East Khandesh in 1908, though these results, which are quoted in the Bombay Forest Report for 1908-9, are interesting so far as they go. The object of these experiments was to ascertain the percentage of mortality among natural seedlings in thirty-one different patches. Several of these patches were accidentally burnt and others were purposely burnt in the dry season following the seeding; the results showed a larger percentage of survivals in the burnt than in the unburnt plots. Protection from fire and grazing may have an adverse effect under certain conditions in inducing a rank growth of grass.

3. *Soil conditions.* Under natural conditions the degree of soil moisture necessary for the normal development of the sapling is not ordinarily attained until the taproot has penetrated some distance into the subsoil, and hence the annual dying back of the stem, which has already been described. It is generally agreed that the shallower the soil and the harder and more impermeable the subsoil the more difficult it is for the seedling to establish itself, the progress of the taproot being slower and the period during which the plant is exposed to the risks of desiccation being longer. Conversely, it might be expected that anything which will tend to increase the porosity of the soil or prevent desiccation will materially assist in the establishment of the seedling; and there is ample evidence to prove that this is the case. To begin with, the Dehra Dun experiments described above clearly demonstrate the beneficial effect of regular weeding in stimulating the development of the seedling, this stimulus being due, in the earlier stages at all events, at least as much to the loosening of the soil as to the actual removal of weeds. Soil-aeration of this kind is now an accepted factor in the case of plant growth, not only providing a supply of air to the roots, but also furnishing an air-cushion which conserves the soil-moisture and prevents desiccation. In the dry regions in which *Hardwickia binata* grows it is of special importance, and there is no lack of evidence to show that loosening the soil has assisted in establishing reproduction. Thus the abundance of natural reproduction on abandoned cultivation has been commented on on more than one occasion, while there are numerous instances of seedlings establishing themselves readily on hoed ground on which seed has been sown. Mr. E. E. Fernandez has recorded some interesting observations bearing on this subject in an article entitled *The Treatment of Hardwickia binata*,¹ from which the following quotations, relating to the Nimar district, are taken: 'Up to the reservation of Punasa . . . every attempt . . . had been made to get rid of the forest and replace it by field crops, but the

¹ Ind. Forester, xxix (1903), p. 517.

forest reappeared almost as fast as it was destroyed. . . . The ground was never completely cleared of forest ; numerous trees of seed-bearing age were left scattered all round and over the fields. The seed fell from these trees on the newly broken land, now at last also freed to a great extent of grass, and the resulting seedlings came up under the most favourable condition for survival. The subsequent cultivation of the soil, limited to a mere scratching of the soil, left an appreciable proportion of the seedlings uninjured to continue their development, and as the field was abandoned as soon as the soil showed the first signs of exhaustion, the young plants were left in complete possession of the ground. . . . During the seven years that I was able to continue my observations before I was transferred to the United Provinces the seedlings of pre-reservation days continued to strengthen themselves and develop, but no new contingent of seedlings survived to swell their numbers. . . . The seedlings are as usual produced in countless numbers after every periodic gregarious seeding, but, being unable to push their taproots down deep enough, they all perish in their very first year.' Again : ' There is no doubt whatsoever that the death of the seedlings is due to their inability to force their long slender taproot down deep enough through the matting of grass roots occupying the soil everywhere to a depth of 1-2 ft.'

We have already seen that Mr. Witt's experiments appear to disprove the theory that the taproots of the seedlings are unable to force their way through the roots of the grass, and to show that the mortality among the seedlings is due to drought. At the same time, the observations of Mr. Fernandez indicate that seedlings appearing on land which has been broken up for cultivation and subsequently 'scratched' for a few years have succeeded in establishing themselves, whereas in the same locality seedlings appearing on land which has reverted to grass have failed to do so. This affords room for a strong presumption that success in the former case was due to soil-aeration, and that Mr. Fernandez was not very far wrong in attributing failure in the latter case to the grass roots, though the failure was probably due not so much to their direct obstructive action as to the introduction of an unfavourable factor possibly connected with deficient soil-aeration, caused, in part at least, by the binding action of the roots.

To quote further examples of establishment of reproduction on broken soil, Shyam Sunder Lal¹ writes of conditions in Indore state : ' The natural seed regeneration in the seeding year (which is generally every third year) is so profuse, that many thousands of small seedlings per acre can be counted in the forests. A large proportion of these, however, die from several causes, but this kind of regeneration, on old sites of cultivation, has always been noticed to thrive extraordinarily, and it is an object lesson to be remembered that breaking up of land in the vicinity of anjan seed-bearers, either by means of ploughs or otherwise, helps the young seedlings considerably and gives much better results. . . . This has been tried in our forests with good results.'

Mr. P. M. Lushington,² referring to a remarkable plot of natural reproduction in the Malappakonda reserve, Anantapur district, which is known to have come up within recent years near old seed-bearers on cultivated land acquired at settlement, remarks : ' A lesson can I think be learned from this

¹ Ind. Forester, xxxvii (1911), p. 65.

² Inspection Note, 1913.

area, that we can aid the regeneration of this valuable species in places where there is a reasonable amount of soil by merely ploughing it up in the vicinity of existing trees.'

Mr. S. Srinivasulu Naidu¹ writes of experiments in Buldana: 'In the Moegaon felling series of the Amdari Reserve the experiment consisted in closing the area to grazing and breaking up the soil for a radius of fifty feet round a number of marked seed-bearers in a forest which had been subjected to heavy grazing and in which natural regeneration was practically absent at the time the experiments were started. The sample plots are situated close to the Buldana-Malkapur road and the grass in the locality is cut over once or twice in the year. Some of the sample plots have been specially kept clear of heavy grass by weeding, while others have been left without treatment, but in both cases the results are generally satisfactory and often excellent.'

Mr. L. S. Osmaston² notes with regard to Khandesh: 'Although anjan often reproduces itself well by seed naturally, still such reproduction is considerably helped and better ensured by breaking up the soil under a seeding tree; on such broken up soil the seedlings are not only more numerous but better grown, more vigorous and more likely to withstand the first hot weather than those on unbroken ground.'

4. *Protective shade.* The value of protective shade has already been indicated in connexion with the dying of seedlings through drought and the beneficial effect of the protection afforded by grass in dry localities. We have, however, already seen that there is a strong presumption that in certain cases a growth of grass may produce adverse soil conditions sufficient to counterbalance the beneficial effects of the grass, and it remains to be seen if any other form of protection is likely to secure the establishment of natural reproduction. As far as is known there are no records of definite experiments to ascertain the effect of the protective shade of trees and bushes and how this shade should be applied. There are, however, suggestions and observations which may be quoted. Thus, in 1903, Mr. T. B. Fry³ suggested the open condition of the forests in Bombay as one possible cause of mortality among seedlings, and thought something might be gained by introducing nurses to protect the young plants from the fierce heat of the sun. Mr. Witt⁴ states: 'From observations made, we are strongly of opinion that shade as a protection to seedlings during the first three or four years' growth, against the heat and the dry winds of the hot season, is a *sine qua non* in the successful regeneration of anjan forests.' And again: ⁵ 'The more the seedlings are exposed to the direct rays of the sun and the scorching hot winds of the dry season the more will they transpire, and the more moisture will they require. Consequently, if in addition to the protecting growth of grass the seedlings also have overhead cover, we might expect it to act in a similar manner. And this is exactly what we have observed. Wherever the seedlings have been protected by a growth of grass and overhead shade, they have survived in far greater numbers than those in free and exposed positions.'

Mr. L. S. Osmaston⁶ also records the following observations: 'Bushes

¹ Working Plan for the Buldana Forest Division.

² Ind. Forester, xxxv (1909), p. 380.

³ *Ibid.*, xxix (1903), p. 527.

⁴ *loc. cit.*, p. 85.

⁵ *loc. cit.*, p. 126.

⁶ Ind. Forester, xxxv (1909), p. 380.

of *Cassia auriculata*, *Gymnosporia montana*, and *Rhus parvifolia* are of great use in regeneration : it is surprising how many healthy *Hardwickia* seedlings one finds right under the shade of such bushes : this is apparently due to the shelter afforded from the heat of the direct sun's rays and to the fact that under such bushes there is an accumulation of soil and humus ; also where cattle grazing is allowed such bushes protect the seedlings from being eaten. I have not yet come to a conclusion as to whether such bushes should be cut level with the ground when the *Hardwickia* seedlings in their shade have attained a certain age.'

5. *Climatic factors.* We have already considered at some length the adverse effects of drought on the development of the seedling and the establishment of natural reproduction. The factor of rainfall is one which seems to require further study, and in this connexion the following quotation from the Yerramalais working plan¹ is of interest :

'Most of the seedlings die out in the prolonged drought which follows the rains and continues for about nine months. It is only when this drought is interrupted by rainfall that some of them survive. Therefore it is usual to come across a group of young seedlings in one place and a patch several years older at another. For successful regeneration rainfall should be regular or the seedling should be able to pass the strata affected by drought before it is killed.'

The extent and distribution of the seasonal rainfall may very well be presumed to have an effect on the establishment of natural reproduction ; in the absence of direct evidence, however, it seems unsafe definitely to ascribe the establishment of reproduction in patches to favourable years of rainfall, though it is by no means an improbable explanation of the phenomenon.

Conclusions. From the details just given it may be concluded that, given the necessary seed-bearers, factors ordinarily beneficial to the establishment of natural reproduction are porosity and depth of soil, protection in early youth from the heat of the sun, protection from fire and grazing, and probably also favourable rainfall conditions. Adverse factors are stiffness and shallowness of soil, exposure of the seedlings to a hot sun, fire, grazing, and probably adverse rainfall conditions. Under certain conditions a soil-covering of grass may be decidedly beneficial in affording protection from the sun, while under other conditions it may, if sufficiently rank, be a highly noxious factor in preventing the seed from reaching the ground and in suppressing seedlings or causing them to damp off.

There may possibly be other factors affecting the question, but those under consideration give some indication of how natural reproduction may be induced, namely, by ploughing or hoeing up the ground to the leeward of seed-bearers in good seed-years and protecting the resulting seedlings from the heat of the sun. In Nimar, and no doubt in other localities, this protection can be secured, according to Mr. Witt's observations, by allowing the grass to grow up ; under some conditions, however, it may be necessary to keep the soil loose and to clear the grass. In either case the shade afforded by trees and bushes will be beneficial and may even be essential. This last consideration gives a possible clue to the origin of some of the existing crops

¹ Working Plan for the Yerramalais, West Kurnool, J. Tapp, 1913.

of *Hardwickia* in localities where natural reproduction does not appear now ; these crops may have come up under the shelter of previously existing trees. On the other hand, it is not improbable that some of them are the result of natural reproduction which appeared on land at one time under cultivation.

ARTIFICIAL REPRODUCTION. *Hardwickia binata* has been propagated artificially to some extent both within and without its natural habitat, partly by direct sowing and partly by transplanting, though it is generally agreed that the former is the more successful. Haines says it has been extensively planted in Nagpur, where it grows well on the trap hills ; also that it is best sown *in situ*, and remains very small for the first two or three years. It has been transplanted with success on the Talankheri (Seminary) hill, Nagpur, after pruning the stem and root. In Saugor patch sowings have been carried out with varying success ; in some cases the seedlings have attained a height of 3 ft. in three years. Mr. Fernandez ¹ says it bears transplanting well, and recommends transplanting superfluous seedlings from patches from the third year onwards, younger plants not being robust enough. This does not agree with my experience at Dehra Dun, where direct sowings were found to be much more successful than transplanting, whether with pruned or intact stem and roots. The difficulty of transplanting is corroborated by Mr. L. S. Osmaston,² who writes : ' It is hopeless to try and transplant the seedling, however young the seedling may be : artificial regeneration can therefore only be successful if sowing takes place where the tree is to be permanently. When sowing it is best not to cover the seed with soil at all, or at any rate to only partially cover it.' I have found it advantageous to cover the seed lightly, as this not only prevents it from being blown away but also protects the radicle from the attacks of birds during germination.

The experience of Shyam Sunder Lal regarding transplanting in Indore is, on the other hand, favourable. He writes as follows : ³

' As regards its suitability for transplanting, I can say with confidence that it transplants as well as any other tree. I have transplanted several hundred small seedlings to fill blanks in the forests and always with good results. In the year 1908 I sent more than a dozen trees, 9 ft. in height, from our forests to the Residency compound at Indore, and every one of these plants is fully established, and out of the two 18-inch girth trees which I had sent to Indore from a distance of 20 miles, one died, the other is perfectly healthy. In the Rajputana-Malwa Railway Executive Engineer's compound at Mhow, several hundred seedlings were transplanted six or seven years back, and these are at present 10 to 12 ft. high and look quite promising.'

In the Yerramalais working plan it is stated that broadcast sowing on ploughed land as well as dibbling have been tried without success, for although germination was good nearly all the seedlings were killed off by drought. The system found most successful is to sow in contour trenches 6 ft. by 2 ft. by 1½ ft., in which the soil at the bottom has been loosened, and on mounds of earth thrown up alongside. The seedlings in the trenches are shaded from December or January until the following rainy season by laying sticks across the trenches and covering them with a thick layer of grass weighted with stones,

¹ Ind. Forester, xxix (1903), p. 527.

² *Ibid.*, xxxv (1909), p. 380.

³ *Ibid.*, xxxvii (1911), p. 64.

a length of 1 ft. being left uncovered at the end of each trench to admit light and air.

Various methods of experimental sowing on trap formation in the dry climate of Nasik (rainfall about 24 in.) have been described by Mr. L. S. Osmaston.¹ Dibbling the pods proved a failure. Broadcast and line sowings without preparation of the ground, as well as sowing in pits, were only moderately successful. Mound sowings gave more success, especially in the case of fairly large mounds 2½ ft. high, and 2 ft. and 7 ft. in diameter at the top and base respectively, while broadcast sowings on ploughed ground were decidedly successful, particularly where the ploughing was followed by harrowing to remove the tufts of grass. The greatest success, however, was attained by means of line sowings in combination with the raising of agricultural crops, a method which has generally been found to be the most successful in raising forest plantations in dry regions. These sowings are described in the *Indian Forester*, vol. xxxiii (1907), p. 266. The field crops employed were sesamum, cotton, and the lesser hemp, the sowing being preferably carried out by lessees under a two years' lease. Two separate methods were tried as follows : (1) In the first year the lessee cultivated field crops only, while in the second the tree seeds as well as field crops were sown, the area being weeded twice in the first rains. One line of tree seeds was sown to three lines of field crops, and the lines being about 1 ft. apart the distance between the lines of tree seeds was about 4 ft. (2) The tree seed was sown in the first year of the lease, four adjacent lines of tree seeds (forming a strip 3 ft. wide) alternating with strips of field crops 8 ft. wide ; in the second year the lessee cultivated field crops between the strips of tree seedlings and weeded and sowed up blanks in the latter. In departmental sowings of this kind the cost of formation for the first three years amounted to Rs. 28-11-0 per acre and the receipts from the produce of the field crops Rs. 32 per acre, showing a profit of Rs. 3-5-0 per acre.

Similar sowings with field crops in Berar, which have also proved successful, have been described by Mr. C. G. Rogers.² The field crops employed were sesamum, cotton, and *arhar* ; the *Hardwickia* seedlings reached a height of 1½ to 2 ft. in two years and four months.

SILVICULTURAL TREATMENT. At present *Hardwickia binata* is treated under a variety of methods of working. In various localities the system employed is coppice-with-standards, in which *Hardwickia* constitutes the standards and miscellaneous species the coppice. In the Dhulia and Pimpalner ranges of West Khandesh the treatment prescribed is improvement fellings with artificial reproduction of *Hardwickia* by broadcast and by agri-silvicultural sowings.³ Similar treatment is prescribed for the Yerramalais, West Kurnool, regeneration being effected by means of trench and mound sowings already described. In Buldana a somewhat similar method of working is in operation experimentally.⁴ The treatment consists of the removal, under a felling cycle

¹ Ind. Forester, xxxiii (1907), p. 177.

² *Ibid.*, xxxvii (1911), p. 8.

³ Working Plan for the Anjan and Scrub Jungles of Dhulia and Pimpalner Ranges, West Khandesh, J. Hamilton, 1914.

⁴ Working Plan for the Buldana Forest Division, Berar Circle, Central Provinces, S. Srinivasulu Naidu, 1913.

of twenty years, of over-mature and deteriorating stems subject to the retention of a minimum of 20 seed-bearers per acre, combined with regeneration by breaking up the soil and sowing broadcast : *Hardwickia* is felled at a height of 18 in. from the ground.

Under 'natural reproduction' (conclusions) and 'artificial reproduction', pp. 357-9, methods are suggested for obtaining regeneration naturally and artificially, and it will generally happen that even if the former is secured it will require to be supplemented by the latter. Important points are the retention of sufficient shade until the young crop is established, protection from fire, and closure to grazing until the saplings are out of reach of animals, that is, usually for ten years or even more.

RATE OF GROWTH. The annual rings are not very distinct, but according to Mr. Witt they can frequently be made out with a good lens by the numerous pores filled with resin at the inner edge of the ring. Gamble says the rate of growth is usually about 10 rings per inch of radius, which gives a mean annual girth increment of 0.63 in. In dry localities on poor shallow soil the growth under natural conditions may be extremely slow. Mr. E. D. M. Hooper writes : 'The natural growth of the young tree in the dry Deccan is undoubtedly very slow, and I have watched the species in the Malpangudi and Sherbi reserves of Bellary for the past twenty years and the stems have scarcely progressed.' Trees raised artificially and tended grow much more rapidly. Mr. Ananda Rao¹ says : 'Some planted in the Nandyal compound about twelve years ago are about 25-30 ft. high and about 6 in. in diameter at breast height.'

Allusion has already been made, under 'the seedling', to the fact that the rate of growth of saplings can be traced by the annular marks on the stem, which denote each year's growth. Mr. Witt² estimates in this way that the average rate of height-growth of a normal sapling in Nimar, from a height of 3 ft. upwards, is 9-12 in. a year, and that allowing for the period of dying back in the early stages a natural sapling 10 ft. high would be about twenty years old. He also quotes some interesting figures showing the estimated rate of growth of trees on trap and on sandstone respectively. Thus forty-five trees, planted along roads in the civil station of Khandwa on shallow soil overlying trap rock, were thirty-seven years old. Measurements gave the following results :

Average height	35 ft.
Mean annual height increment	9.3 in.
Average diameter (at breast height)	10.1 in.
Corresponding girth	2 ft. 8 in.
Mean annual girth increment (including bark)	0.86 in.
Number of rings per inch radius (after deducting 1 in. thickness of bark)	9 rings

As regards growth on sandstone, ring-countings made by him in respect of ten trees of various ages showed an average of between 13 and 14 rings per inch of radius, representing a mean annual girth increment of 0.46 in.

Mr. A. W. Lushington, quoted by Gamble,³ says that planted trees of known age on the Kistna canals gave 2.04, 3.23, 4.54, 6.10, 7.35, 8.43, 9.43, 10.39, 11.33, 12.26, and 13.18 in. diameter for 5, 10, 15, 20, 25, 30, 35, 40,

¹ Working Plan for the Yerramalais Hill Reserves, West Kurnool, 1906.

² *loc. cit.*, pp. 101-2.

³ *Man. Ind. Timbers*, 1902, p. 277.

45, 50, and 55 years respectively. The last corresponds to about 8 rings per inch of radius.

As regards coppice growth, Mr. L. S. Osmaston records the following measurements made in coppice coupes of different ages on trap formation in West Khandesh (rainfall about 20 in.) :

Hardwickia binata : number of shoots per stool and growth of coppice.

Age. years.	No. of shoots per live stump.	Mean girth at breast height of largest shoot. inches.	Mean height of largest shoot. feet.
1	2.8	—	1.4
2	3.0	—	1.6
3	2.6	2.0	6.0
4	2.9	2.7	6.7
5	2.6	6.0	11.7
6	3.5	6.8	12.5
7	2.7	6.3	11.1
8	3.3	4.3	9.6
9	2.5	8.0	13.6
10	2.8	8.8	15.0
11	3.2	11.0	17.0
12	3.4	6.9	11.7
13	2.2	9.8	14.5
14	3.4	11.0	13.9

The average number of shoots per live stump in all the coupes is 2.9.

2. *Hardwickia pinnata*, Roxb. Vern. *Madeyan sampirani*, *koda palei*, Tam. ; *Shurali, kiyavu*, Mal. ; *Chon paini*, Coorg.

A large handsome evergreen tree attaining a height of 100 ft. and a girth of 14 ft., with dark green shining foliage. Leaves with four to seven leaflets 2-4 in. long. Bark dark brown and green, rather rough. Wood moderately hard, dark red or reddish brown, ornamental, used for building and furniture.

DISTRIBUTION AND HABITAT. The tree occurs in the Western Ghats from South Canara to Travancore. It is abundant in the forests of Travancore up to 3,000 ft. In Coorg it is common in the evergreen forests : enumerations by Mr. N. E. Shrigley in 1914-15 gave an average per 100 acres of 58 trees above 7 ft. 6 in. in girth, and 22 trees 6 ft. 9 in. to 7 ft. 3 in. in girth. In the Coorg evergreen forests its chief companions are *Hopea* spp., *Dipterocarpus indicus*, *Vateria indica*, *Dysoxylum malabaricum*, *Artocarpus hirsuta*, *A. integrifolia*, *Calophyllum* spp., *Dichopsis elliptica*, and *Mesua ferrea*.

FLOWERING AND FRUITING. The small white flowers, in dense paniced racemes, appear in February, and the pods ripen in May-June. The pod (Fig. 142, a) is 1.2-2 in. long by 0.8-1.2 in. broad, turgid, woody, compressed, with a single seed in the apical part, indehiscent until germination, when it dehisces slightly at the apex.

GERMINATION (Fig. 142, b-d). Hypogeous. The pod dehisces slightly at the apex, enabling the radicle and plumule to emerge ; these elongate rapidly, while the cotyledons remain within the pod.

THE SEEDLING (Fig. 142).

Roots : primary root long, moderately thick, terete, tapering, flexuose : lateral roots few to moderate in number, short, fibrous, distributed down main root. *Hypocotyl* scarcely distinguishable. *Cotyledons* 0.8-1.2 in. by 0.4-0.7 in., fleshy, remaining within pod. *Stem* erect, glabrous or young

parts minutely puberulous. *Leaves* alternate, compound, earlier leaves with one pair, later leaves with two or three pairs of leaflets, first few leaves abortive and scale-like. Stipules up to 0.15 in. long, falcate acuminate. Common petiole (earlier leaves) 0.4–1.5 in. long. Leaflets with thick petiolules 0.1–0.15 in. long, lamina 1.5–3.5 in. by 0.6–1.2 in., obliquely ovate acuminate, entire, coriaceous, gland-dotted, glabrous or lower surface minutely puberulous in young leaves, lateral veins numerous. The seedling ordinarily attains a height of about 8 in. in the first season, with a taproot 1 ft. or more in length.

The growth of the seedling appears to be somewhat slow. Mr. H. Tireman informs me that young plants raised from seed sown in 1914 under moderate shade in an abandoned *kumri* in Coorg had an average and maximum height in January 1918 of 0 ft. 11 in. and 2 ft. 9 in. respectively.

RATE OF GROWTH. Bourdillon says that the annual rings are marked by dark lines, and that the rate of growth is about 12 rings per inch of radius, giving a mean annual girth increment of 0.52 in.

5. SARACA, Linn.

Saraca indica, Linn. Asoka tree. Vern. *Asok*, *ashok*, Hind.

Though not an important forest tree, this tree is often planted for ornament or for religious purposes; it is one of the most sacred trees of the Hindus and Buddhists, the flowers being much used for religious ceremonies and temple decoration. It is found wild along streams, or in the shade of the evergreen forests, in the Khasi hills, Chittagong, Arakan, Tenasserim, Upper Burma, the Northern Circars, and the west coast of Bombay. The clusters of fragrant orange or red flowers appear from January to April or May. The tree is interesting as furnishing an example of drooping young leaves without chlorophyll, like those of certain other evergreen trees, for example *Amherstia nobilis*, *Mesua ferrea*, *Mangifera indica*, *Polyalthia fragrans*, and others. The leaflets of the young leaves are red in colour, thin and flaccid, and hang vertically downwards for some time after attaining full size.

6. AMHERSTIA, Wall.

Amherstia nobilis, Wall. Vern. *Thawka*, Burm.

This, one of the most beautiful flowering trees in the world, is an evergreen tree indigenous in Tenasserim and cultivated in the moister parts of Burma and southern India. The flowers are crimson to yellow or salmon pink, in large candelabrum-like pendulous racemes hanging amongst the handsome foliage. The young leaves are of a rich red or purplish colour and hang flaccid (see under *Saraca indica* above). The tree is somewhat difficult to cultivate, being delicate when young and requiring a rich soil and a warm moist equable climate. It may be raised from seed in pots or baskets, but can best be propagated by layering in the hot season and planting out during the rains. It is cultivated successfully in Ceylon, but seldom ripens its seeds there; it flowers during the greater part of the year, but chiefly from January to March.

7. TAMARINDUS, Linn.

Tamarindus indica, Linn. Tamarind. Vern. *Imli*, *amli*, Hind.; *Hunase*, Kan.; *Chinch*, Mar.; *Puli*, Tam.; *Chinta*, Tel.; *Pulinje*, Coorg; *Magyi*, Burm.

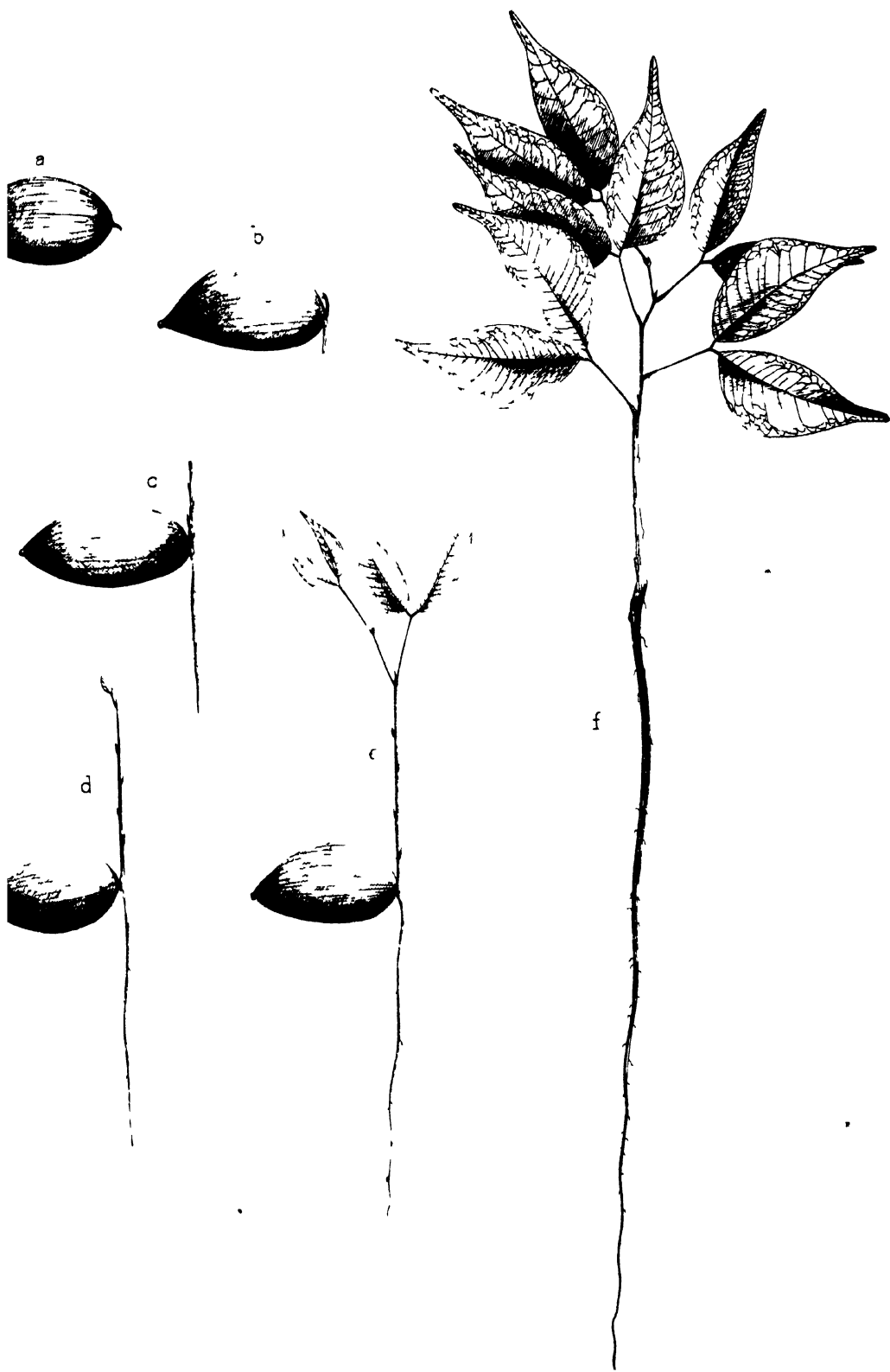


FIG. 142. *Hardwickia pinnata*. Seedling $\times \frac{1}{2}$.
 a, fruit ; b-d, germination stages ; e, seedling one month old ; f, seedling six months old.

A large usually evergreen tree attaining a height of 100 ft. and a girth of 15 ft. or more, with a spreading rounded crown and pinnate leaves with ten to twenty pairs of leaflets about 0.5 in. long. Bark dark grey, moderately thick, deeply cracked. Wood hard and close grained, used for rice-pounders, oil and sugar mills, tools, furniture, and turnery. The tamarind is not a forest tree, but is largely planted for shade and ornament and for the sake of its pods, which are used as an astringent and aperient and for making condiments. It is an excellent avenue tree, being always in leaf and having a spreading crown. Mr. A. E. Wild records a tree 25 ft. 6 in. in girth at Kara, Gaya.

DISTRIBUTION AND HABITAT. Said to be indigenous in Abyssinia and central Africa. Largely planted in India along roads and avenues, and in and around villages; frequently run wild. Tamarind groves in the forest often mark the sites of deserted villages. It thrives only in the warmer parts of India, and though planted as far north as the Punjab it does not ripen its fruits, nor does it flourish. In Burma it is one of the commonest of village trees in the dry zone.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The tree is never leafless except in very dry localities, where it is sometimes leafless for a short time in the hot season. The new leaves appear in March–April. The small yellow and red variegated flowers appear from April to June (also in October. Haines), and the pods ripen from February to April. The pods are brown. 3–6 in. long, 0.5 in. thick, with a brittle epicarp, filled with a dark brown fibrous acid pulp containing three to ten brown smooth compressed seeds (Fig. 143, *a*). The pods are readily eaten by monkeys, which are instrumental in scattering the seeds. The germinative power of the seed is fairly high (average 66 per cent. in tests at Dehra Dun, where conditions are not favourable).

GERMINATION (Fig. 143, *b–e*). Epigeous. The radicle emerges from one end of the seed and descends rapidly. The hypocotyl elongates, arching slightly, and raises above ground the cotyledons enclosed in the testa. The latter falls to the ground when the cotyledons expand.

THE SEEDLING (Fig. 143).

Roots: primary root long, wiry, flexuose: lateral roots numerous, moderately long, fibrous, distributed down main root. *Hypocotyl* distinct from and thicker than root, 1.5–3.5 in. long, slightly compressed, finely tomentose. *Cotyledons* sessile, 0.5–0.7 in. by 0.35–0.5 in., plano-convex, thick, fleshy, unequally ovate, orbicular or obovate, apex rounded, base projecting about 0.1 in. behind point of insertion. *Stem* erect, terete or slightly compressed, wiry, tomentose; internodes 0.3–1 in. long. *Leaves* paripinnate, first pair opposite, subsequent leaves alternate. Stipules 0.2–0.3 in. long, falcate acuminate, pubescent. Rachis 1.1–3 in. long, pubescent, terminating in a bristle. Leaflets 6–10 pairs, opposite, sub-sessile, 0.4–0.9 in. by 0.15–0.3 in., linear oblong or rhomboidal, obtuse or slightly emarginate, entire, pubescent, glaucous beneath, darker above.

The early development of the seedling is fairly rapid under favourable conditions, a height of 2 ft. or more in the first season and 4 ft. or more in the second season being attainable with regular weeding and watering. A long taproot is developed early; this may attain a length of over 1 ft. within two months of germination. Weeds greatly hinder the growth of the seedling, which responds in a marked degree to weeding. The young plant grows best

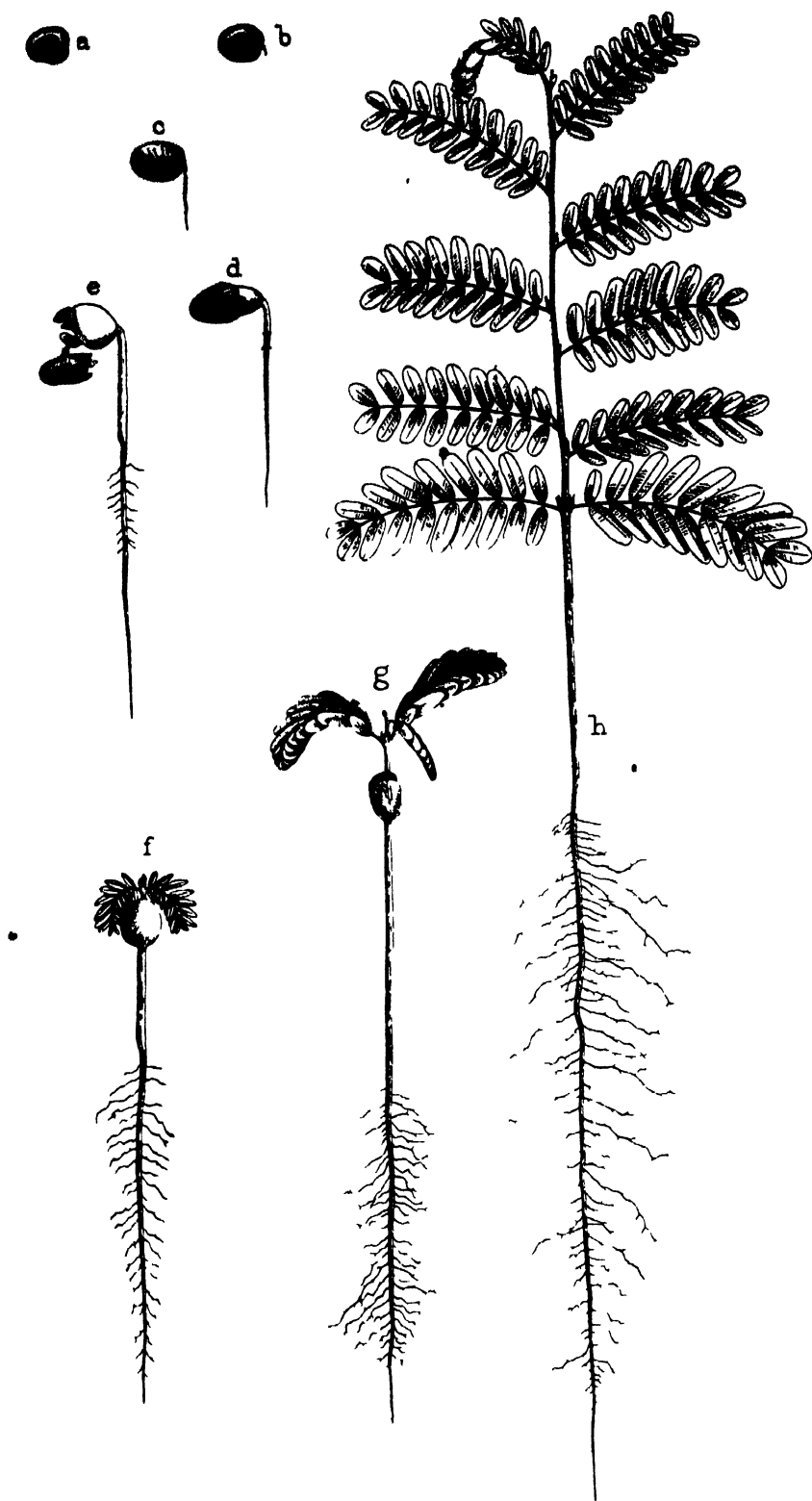


FIG. 143. *Tamarindus indica*. Seedling $\times \frac{3}{8}$.

a, seed ; b-e, germination stages ; f-h, development of seedling to end of first season.

in a porous soil and if sheltered from the sun in the earlier stages ; it is very sensitive to frost.

SILVICULTURAL CHARACTERS. The tree is not exacting as regards soil, though it thrives best on deep alluvium : Haines says it has become naturalized among granite rocks near Kuru, Chota Nagpur. It is sensitive to frost, but withstands drought, having remained unaffected in the severe drought of 1899–1900 in the Deccan. The tree produces root-suckers. Owing to the fact that under its shade the ground is usually bare it is one of the most suitable trees for planting along fire-lines, for which purpose it has been employed in Mysore.¹ Its growth is somewhat slow.

ARTIFICIAL REPRODUCTION. The tree is not difficult to propagate, whether by direct sowing along ploughed or hoed lines or by transplanting : in either case regular weeding and loosening of the soil stimulate growth. The seed should be sown about April in raised nursery beds composed of light porous soil, the beds being kept regularly watered and weeded : germination ordinarily commences in about five to ten days. Experiments at Dehra Dun showed that transplanting can be most successfully carried out during the first rains before the taproot reaches too great a length. Transplanting with entire root and stem in the second rains is more difficult and is liable to failure unless watering can be carried out for some time after. A fair amount of success has been attained at Dehra Dun by transplanting during the second rains after pruning the stem and taproot down to a length of about 2 in. and 9 in. respectively. Successful planting along fire-lines in Mysore has been carried out by raising seedlings in tile pots and planting them out 9 ft. by 9 ft. in pits 3 ft. cube, no subsequent watering or attention being required except to hoe up the soil round the plants once a year.

8. CASSIA, Linn.

Species 1. *C. Fistula*, Linn. ; 2. *C. renigera*, Wall. ; 3. *C. siamea*, Lam. ; 4. *C. auriculata*, Linn.

1 *Cassia Fistula*, Linn. Indian laburnum. Vern. *Amaltas*, Hind. ; *Bahawa*, Mar. : *Kakke*, Kan. . *Konnai*, Tam ; *Rela*, Tel. ; *Sonaru*, Assam ; *Ngu*, Burm. (Fig. 144.)

A moderate-sized deciduous tree with a rather open crown ; leaves paripinnate with four to eight leaflets 2–6 in. long. Bark about 0.25 in. thick, in younger trees smooth, light grey, reddish brown inside, in older trees reddish brown, exfoliating in hard scales. This is one of the most beautiful of Indian flowering trees. Wood hard and durable, in demand for house-posts, carts, and agricultural implements. The pulp of the pods is a strong purgative (the *Cassia Pulpa* of the British Pharmacopoeia), while the bark is much in demand for tanning.

DISTRIBUTION AND HABITAT. Common in deciduous forests throughout the greater part of India and Burma, ascending to 4,000 ft. in the Himalaya ; also in Ceylon. The tree is not gregarious, but is scattered in mixed deciduous forests, often of a somewhat open type : it occurs fairly frequently in sal forest. Sometimes it approaches gregariousness in localities frequented by monkeys

¹ Ind. Forester, ix (1883), p. 143.

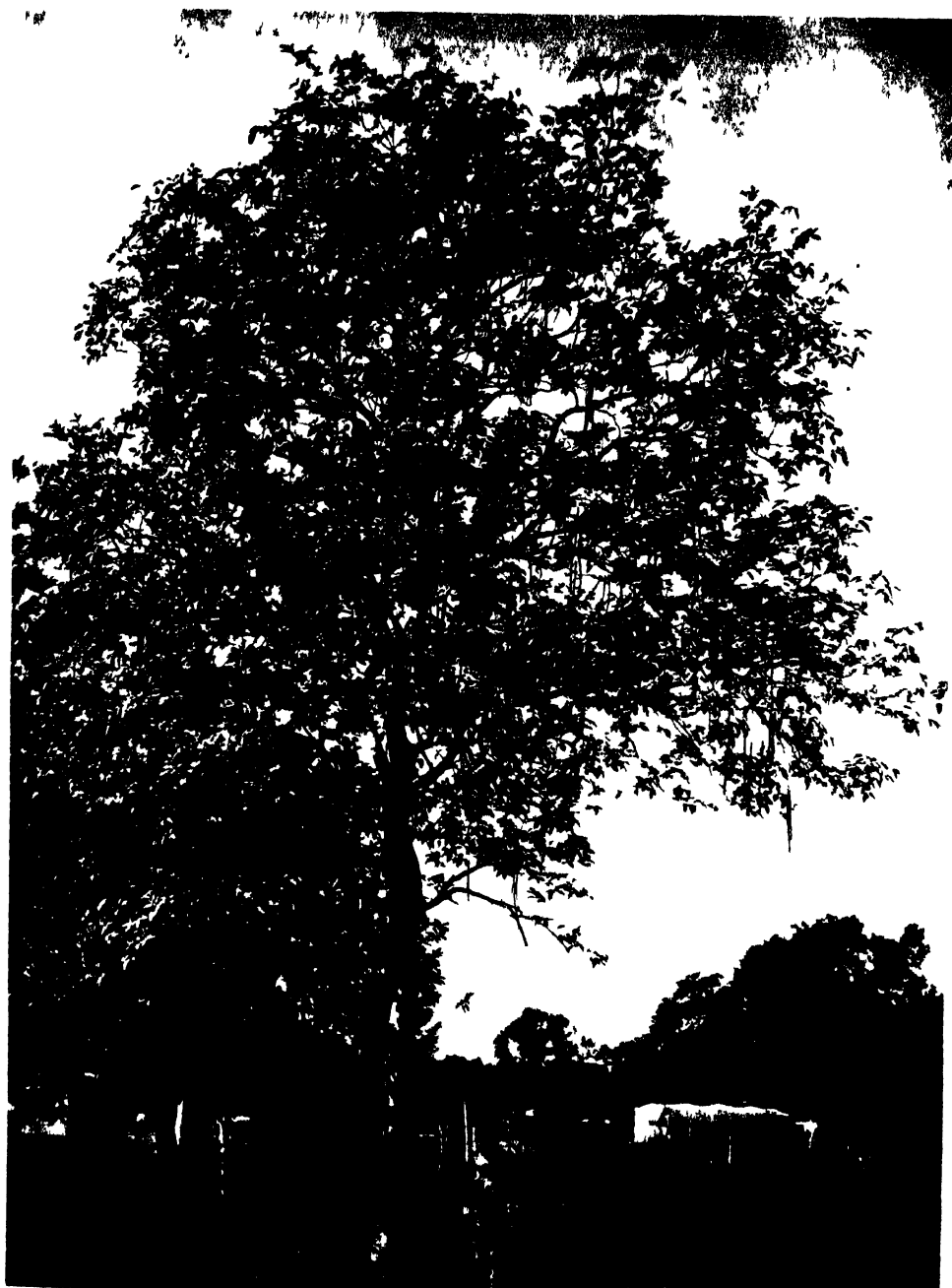


FIG. 144 *Cassia Fistula* in fruit Dehra Dun, United Provinces.

(see under 'natural reproduction', p. 368). It is found on a variety of geological formations and will grow on poor shallow soil, as on the dry outer slopes of the Himalaya. In climatic requirements it shows a wide range. In its natural habitat the absolute maximum shade temperature varies from 100° to 120° F., the absolute minimum from 25° to 65° F., and the normal rainfall from 20 to 120 in. or more.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The tree is leafless for a very short time, or hardly at all, between March and May, the new leaves appearing in April-May; these are bright green or sometimes a beautiful rich copper colour. The long pendulous racemes of large bright yellow flowers appear chiefly with the new leaves from April to June, but it is no uncommon thing to find the tree in flower even as late as September, particularly in dry years. The long cylindrical pods develop rapidly, reaching almost full length but not full thickness by October, when they are still soft and green. By November they are full-sized but still green and unripe; they commence ripening in December and continue ripening from January till March or April. The ripe pods are 1-2 ft. long or sometimes more, 0.75-1 in. in diameter, pendulous, cylindrical, dark brown, smooth, hard, indehiscent, septate into numerous one-seeded cells, the seeds being embedded in a dark brown sweetish pulp which is a strong purgative. The ripe pods hang for some time on the tree, commencing to fall about April-May, and continuing to fall in the following months: old pods may often be found on the trees in September or later along with the new half-grown green pods.

The seeds (Fig. 145, a) are 0.3-0.4 in. by 0.2-0.3 in., ovate, compressed, light brown, hard, smooth, shiny, with a moderately hard testa and a horny albumen. About 2,500 weigh 1 lb. Like many other hard leguminous seeds, those of *Cassia Fistula* take some time to germinate, some lying a whole year in the ground before doing so, even if regularly watered. Boiling the seeds for about five minutes before sowing has been found to give very good results in stimulating germination.¹ Tests carried out at Dehra Dun showed that the seeds retain their vitality unimpaired for at least two years. It was found that seed from pods one year old germinated more quickly than that from fresh pods, though the percentage of sound seeds in the former may be low owing to insect attacks. As regards the identity of the insects which do much damage by attacking the seeds within the pods, specimens of infected pods collected in the Siwaliks in December 1910 were kept under observation; from these were bred out (1) from May 4 to June 5, 1911, moths identified as *Trachylepidia fructicassiella*, Rag., and (2) from May 4 to 13, 1911, beetles identified as *Caryoborus gonagra*, Fabr.²

GERMINATION (Fig. 145, b-e). Epigeous. The radicle issues and the hypocotyl arches slightly, raising above ground the cotyledons enclosed in the testa, which soon falls, along with the albumen, when the cotyledons expand.

THE SEEDLING (Fig. 145).

Roots: primary root long, terete, tapering, wiry, yellow turning brown, glabrous: lateral roots numerous, fibrous, distributed down main root:

¹ Forest Report of Bihar and Orissa, 1917-18.

² Lefroy, Indian Insect Life, pp. 351 and 509. See also Ind. Mus. Notes, iv. 106, for damage by the tortricid moth *Cryptophebia carpophaga*, Wlsm.

nodules present. *Hypocotyl* distinct from root, 1-2.3 in. long, terete, tapering upwards, tender and green at first, becoming brown and wiry, minutely pubescent. *Cotyledons* sessile or very shortly petiolate, thin, plano-convex, somewhat fleshy, 0.7-0.8 in. by 0.4-0.5 in., elliptical oblong, apex rounded, base obtuse, entire, green, glabrous, 5-veined from the base, the three central veins more distinct than the lateral two. *Stem* erect, terete, wiry, pubescent; internodes 0.2-0.5 in. long in young stages. *Leaves* alternate or first pair opposite or sub-opposite, compound, paripinnate, earlier leaves with two pairs of leaflets, followed by leaves with three, then four pairs. Stipules minute, linear. Rachis 0.3-1.5 in. long in first season, pubescent. Leaflets opposite, very shortly petiolate, 0.5-1.7 in. by 0.2-0.5 in. in first season, unequally ovate lanceolate, acute, entire, pubescent, venation reticulate. Early leaves small, successive leaves becoming larger.

The effect of weeding and watering on the development of the seedling is most marked. Various plots of seedlings, some weeded and watered and others left unweeded and unwatered under purely natural conditions, were kept under observation at Dehra Dun, and the following measurements of the plants were recorded :

Cassia Fistula : measurements of seedlings.

Treatment.	Height at end of season.			
	1st.	2nd.	3rd.	4th.
Plants regularly weeded and watered	0 ft. 6 in.- 2 ft. 0 in.	2 ft. 0 in.- 12 ft. 10 in.	Maximum 15 ft.	--
Plants not weeded or watered	Maximum 0 ft. 9 in.	Maximum 1 ft. 10 in.	9 in.- 2ft. 8 in.	5 ft.-8 ft.

This indicates that under natural conditions the seedling develops slowly for the first few years, after which more rapid growth takes place. A fairly long taproot is produced at an early stage.

Seedlings are somewhat frost-tender, but have good power of recovery. If exposed to the sun during germination they are sensitive to drought, and the protection afforded by a covering of earth or a moderate growth of grass is useful: during the rains, however, much mortality occurs owing to the damping off of the seedlings where there is a heavy growth of weeds. In northern India the old leaves of natural seedlings drop about February, and new growth commences in March or early April.

SILVICULTURAL CHARACTERS. *Cassia Fistula* stands a moderate amount of shade. It is not frost-hardy, and suffered severely in the great frost of 1905 in northern India. In the abnormal drought of 1907 and 1908, which seriously affected the forests of Oudh, it proved to be decidedly hardy. It is not readily browsed, even by goats. It coppices vigorously and produces root-suckers freely from a root-system which is partly superficial. As already stated, it is not exacting as regards soil, and may be found on poor shallow soils.

NATURAL REPRODUCTION. As the natural reproduction of this tree was something of a mystery, I made a special study of it in 1910 and following years, with interesting results, for it appears to furnish an instance where animal assistance is necessary in obtaining natural reproduction, and so far no case has yet been observed of reproduction having been effected without the agency of animals.



FIG. 145. *Cassia Fistula* SEEDLING $\times \frac{1}{2}$
a--Seed b - e Germination stages f h- Development of seedling during first season

As already mentioned, the pods ripen from December–January onwards, hanging on the tree often for many months : they commence falling about April–May, continuing to fall until September or even later. After falling they lie on the ground, where they may be found in quantity during the succeeding cold and hot seasons. If pods are collected from the ground during these seasons and broken open each seed will be found loose in its own cell, the pulp having dried up : many of the seeds will as a rule be found to be eaten by grubs, while those which are not attacked will be quite sound, and in fact tests have shown that they retain their vitality for at least two years. Later in the season, and throughout the rains, pods lying untouched on the ground continue in much the same state, their hard outer shells often becoming partially eaten by white ants, but no sign of the germination of the seed being apparent.

In order to determine if possible what happens to the pods on the ground and how reproduction is effected, ripe pods were collected in March 1911 and laid on the ground on a marked plot at Dehra Dun with the view of periodical observations being made. Within a week the plot was discovered by jackals, which broke the pods up with their teeth in order to eat the pulp, scattering the seeds about the plot. This plot was left in the condition in which it was, with the remnants of the pods and seeds lying about as the jackals had left them. A second plot, however, was laid out alongside the original one, and in it another lot of ripe pods was laid on the ground ; this plot, however, was covered with a strong cage of wire netting to keep animals off, and both plots were subsequently kept under observation, with the following results :

A. *Unprotected plot* (seeds scattered by jackals). (1) First season, germination commenced in July, after heavy rain, and continued throughout August ; 24 seedlings came up, of which 15 damped off during the rains owing to heavy weed-growth, leaving 9 at the end of the season with a maximum height of 8 in. (2) Second season, 10 new seedlings appeared in July from seed which had lain dormant for a year ; of these new seedlings 6, and of the old ones 2, damped off during the rains owing to heavy weed-growth, leaving at the end of the season 11 survivors up to 1 ft. 6 in. in height, of which 7 were old and 4 new seedlings. (3) Third season, the 11 survivors of last year remained alive and in good condition, attaining a maximum height of 2 ft. 8 in. by the end of the season ; more dormant seeds germinated in July, but only 2 seedlings escaped damping off under a growth of weeds, and the total number of seedlings in the plot at the end of the season was 13.

B. *Protected plot* (covered with cage of wire netting to keep off animals). During the first rains the pulp within the pods became mouldy and rotten, but the seeds not attacked by grubs remained quite sound and fertile ; many, however, were destroyed by grubs. The pods were kept under observation for four seasons. The seeds never escaped from them, and no germination took place. The shells of the pods became partly eaten by white ants, and the seeds were also to some extent attacked, though some remained sound until the end of the period of observation. The fact remained that no germination took place from the pods in this plot.

In addition to the observations just recorded many others have been

made in the forest with the view of ascertaining the extent to which animals assist in the natural reproduction of this tree, and no case has yet been met with in which the seed was found to germinate without having been extracted from the pods by animal agency ; on the other hand, the remnants of pods broken up by animals have frequently been met with, and in many cases young seedlings have been found during the rains in the neighbourhood of these remnants. The animals which are known to eat the pulp of the pods, and are therefore useful agents in the spread of the tree, are monkeys, jackals, bears, and pigs ; there are possibly other animals also. Although many of the seeds are scattered near the trees where the pods are eaten, without being swallowed by the animals, some are swallowed, as the seeds have been noticed in their excreta ; in this way not only are the seeds disseminated, but germination is probably accelerated, an important point in the case of hard leguminous seeds of this kind. Some curious instances of natural reproduction traceable to the presence of animals have been observed. In certain localities along the base of the outer Himalaya the tree is so plentiful as to approach gregariousness, and although reproduction is partly from suckers, yet seedlings of various ages are also met with ; such places have always been noticed to be frequented by numbers of monkeys, and there can be little doubt that they are the agents directly responsible for the spread of the tree.

As regards the time taken by the seeds to germinate under natural conditions, the observations already recorded have been confirmed by other observations in similar plots in which the seed has been extracted from the pods and scattered on the surface of the ground, namely, that the seed germinates chiefly during the rainy season after thorough soaking ; only a portion of it may germinate during the first year, some lying dormant until the second or even the third year before germinating. In the case of seed lying on the surface of the ground much mortality is caused during germination by the destruction of the radicle by birds and insects, or through drying up in places exposed to the sun. Where the seed is buried by rain or otherwise, which frequently occurs under natural conditions, germination is more successful. A growth of grass, if not too rank, also protects the germinating seed. High mortality among the seedlings is caused subsequently by damping off where weed-growth is heavy.

Much of the natural reproduction met with in the forest consists of root-suckers ; this is particularly the case on hill-sides, in cuttings, and other places where the surface roots are liable to be exposed.

To summarize, the following facts have been established regarding the natural reproduction of this tree from seed :

1. Reproduction is effected mainly, and perhaps entirely, through the agency of animals (monkeys, jackals, bears, pigs, and possibly others), which break open the pods to eat the pulp and thus scatter the seeds or swallow and disseminate them.

2. The seed germinates during the rainy season, some lying dormant until the second or even the third rains.

3. Germination is favoured if the seed becomes buried, and to some extent if it is protected by a moderate growth of grass ; if the seed lies on the surface of the ground much mortality takes place during germination

owing to the destruction of the radicle by birds and insects, or to its drying up if exposed to the sun.

4. Many seedlings perish in heavy weed-growth owing to damping off during the rains.

ARTIFICIAL REPRODUCTION. The seed germinates tardily, that kept for a year germinating more readily than fresh seed. Certain methods of hastening the germination of hard leguminous seeds have been suggested in the introduction to this order, and these may prove effective. The seed should be sown in seed-beds in drills about 10 in. apart in March or April, and regularly watered; germination ordinarily takes place early in the rains, though some of the seed may lie dormant until the second year, germinating at different times from March onwards. Transplanting requires some care, but it can be carried out satisfactorily while the plants are still comparatively small during the first rains: basket planting is the most satisfactory method, the seedlings being transferred to the baskets in the first rains and planted out in the second rains. It is doubtful if direct sowings can be relied on for forest purposes unless this species is mixed with other species, owing to its uncertain germination: nevertheless, plants which do come up from direct sowings and are kept regularly weeded have been found to develop better than transplants.

SILVICULTURAL TREATMENT. The only satisfactory treatment for this species appears to be coppice, since natural reproduction by seed cannot be depended on over definite areas; the tree is not of sufficient value to raise in regular plantations except as an accessory species in mixture with other trees.

RATE OF GROWTH. The following records of periodical girth measurements in sample plots in the United Provinces show that the growth of trees (as distinct from coppice-shoots) is moderate only:

Cassia Fistula: rate of growth in high forest sample plots, United Provinces.

Number of sample plots.	Forest division.	Number of years under observation.	Number of trees under observation.	Girth class. ft.	Mean annual girth increment for period. in.
2	Siwalik	7 and 12	{ 7 1 3	1-2	0.16
				2-3	0.63
3	Lansdowne	12 and 17		1½-3	0.54

These plots were laid out primarily for the measurement of sal, and it is probable that the *Cassia* trees were dominated or even suppressed, so that the rate of growth exhibited here is probably slower than would be obtained under more favourable conditions.

Gamble's specimens gave about 9 rings per inch of radius, equivalent to a mean annual girth increment of 0.7 in. A cross-section 2 ft. 8 in. in girth in the silvicultural museum at Dehra Dun had 55 rings; this represents a mean annual girth increment of 0.58 in.

The rate of growth of coppice-shoots is fairly rapid while it lasts, but in a small-sized tree of this kind the growth slows down early. Measurements of coppice-shoots one year old in Bhandara, Central Provinces, in 1912-13, showed an average height of 6 ft. 1 in. as against 7 ft. 1 in. for teak. Measurements recorded by Mr. A. F. Broun in 1886 in a coppice coupe nine years old

at Bullawala, Dehra Dun, showed a mean girth of 7.7 in. and a mean height of 11 ft. 8 in. for *Cassia* as compared with 8.6 in. and 16 ft. respectively for sal.

The following figures give the results of measurements made in coppice coupes by Mr. C. M. McCrie in 1910 in Gorakhpur, United Provinces, together with measurements of sal coppice in the same coupes :

Cassia Fistula : rate of growth of coppice, Gorakhpur.

Age. years.	Mean height.		Mean girth.	
	<i>Cassia</i> . ft.	Sal. ft.	<i>Cassia</i> . in.	Sal. in.
2	4.0	3.0	—	—
4	7.6	7.0	2.2	2.0
6	11.0	10.3	3.3	2.9
8	14.0	13.0	4.2	3.8
10	16.4	15.3	5.1	4.8
12	18.5	17.5	5.9	5.8
14	20.3	19.2	6.7	6.7
16	22.1	20.9	7.3	7.5

Measurements made in 1911 in coppice coupes two years old in Gonda, United Provinces, gave the following results :

Mean height	<i>Cassia</i> . 9 ft.	Sal. 9 ft.
Average number of shoots per stool	1.5	1.7

2. *Cassia renigera*, Wall. Vern. *Ngushwe*, *ngusat*, Burm.

A small deciduous tree of the dry zone of Upper Burma, chiefly in dry open scrub forests. It is often cultivated for ornament, and grows and flowers well even in moist climates like that of Rangoon, although in its natural habitat it is accustomed to a dry climate and is capable of growing on comparatively poor soils. The tree has large pink flowers (Prain notes that the Shan hills specimens have yellow flowers); these appear in April and May in short racemes along the bare branches together with the young leaves, and the trees at this time are strikingly handsome. The pods are about 15–18 in. long, cylindrical and pendulous, resembling those of *C. Fistula*. The tree is leafless for some time in the hot season.

3. *Cassia siamea*, Lam. Syn. *C. florida*, Vahl. Vern. *Mezali*, Burm.

A moderate-sized evergreen tree with a dense crown, probably indigenous in Burma and the southernmost part of Madras; largely planted for ornament. The yellow flowers, in large pyramidal terminal panicles, appear mainly in the hot season, but the flowering period is comparatively long, and flowers may often be found at various seasons. The pods are 4–10 in. long, and ripen towards the end of the hot season; they hang in clusters and give the tree a somewhat untidy appearance. The tree grows fairly rapidly and is easy to cultivate; it grows well on moist soils provided the drainage is good.

4. *Cassia auriculata*, Linn. Tanners' cassia. Vern. *Tarwar*, *tarwad taroda*, Mar.; *Avaram*, Tam.; *Tangedu*, Tel.; *Peikthingat*, Burm.

An evergreen often gregarious shrub; leaves paripinnate with eight to twelve pairs of leaflets. It yields the most important tan-bark in India, and on this account is worth cultivation on a larger scale than at present. It is also a useful plant for clothing dry bare rocky ground and poor soil. In Madras it is sown as a green manure crop.

DISTRIBUTION AND HABITAT. Common in the drier parts of the Indian Peninsula from Ajmer and the Jumna river southwards, covering large areas in the Deccan ; also found in the dry zone of Upper Burma. It is common on dry stony hills in open places and in scrub forest ; it occurs also on black cotton soil and on laterite near the sea-coast. It is naturally a species of hot dry regions, where the absolute maximum shade temperature varies from 100° to nearly 120° F., the absolute minimum from 33° to 55° F., and the normal rainfall from 20 to 50 in.

FLOWERING AND FRUITING. The yellow flowers appear at various seasons, chiefly from October to May. The flowering and fruiting seasons overlap, and ripe fruit may be found for a considerable period of the year. The pod is flat, 3-4 in. long by about 0.6 in. broad. The seeds (Fig. 146, *a*) are 0.3 in. long ; about 1,100 weigh 1 oz. Good seeds have no difficulty in germinating, and the percentage of fertility is fairly high. The plant begins to flower and fruit at an early age, usually when about a year old.

GERMINATION (Fig. 146, *b-d*). Epigeous. The radicle emerges and descends ; the hypocotyl elongates, raising above ground the cotyledons usually enclosed in the testa, which falls to the ground with the expansion of the cotyledons.

THE SEEDLING (Fig. 146).

Roots : primary root very long, terete, tapering, woody : lateral roots moderate in number, short to moderately long, distributed down main root. *Hypocotyl* distinct from root, 1-2 in. long, terete, tapering upwards, minutely pubescent when young. *Cotyledons* very shortly petiolate, foliaceous, somewhat fleshy, 0.6-0.8 in. by 0.5-0.7 in., sub-orbicular or broadly obovate, entire, green, glabrous. *Stem* erect, woody, glabrous, young parts green. *Leaves* alternate, compound, paripinnate, first 2-6 usually with 2 pairs of leaflets, subsequent leaves with 3-6 pairs or more. Stipules in young seedlings up to 0.25 in. long, linear or triangular acuminate, auriculate, green, pubescent. Rachis channelled above, sparsely pubescent. Leaflets shortly petioluled, with a filiform reddish gland at the base of each pair, 0.3-1 in. by 0.2-0.5 in., elliptical oblong, obtuse, mucronate, entire, terminal pair larger than remaining leaflets.

SILVICULTURAL CHARACTERS. This shrub does not stand shade or drip from overhead trees, and grows best in open places with an abundance of light. It is sensitive to frost, but stands drought well, growing readily on dry shallow soil. It prefers light porous soil ; on water-logged ground or in soil containing an excess of moisture seedlings are apt to rot. The plant is avoided by goats and cattle, but plants cultivated near Dehra Dun were browsed by deer. It coppices well.

CULTIVATION. The plant has been frequently cultivated in various parts of India, and for the production of tan-bark it is worked as coppice. For tanning cow and buffalo hides the bark from shoots three to five years old gives the best results, whereas for tanning goat and sheep skins that of young shoots two years old is preferred : this refers to unirrigated plants. The rotation has thus to be fixed according to requirements.

For the formation of plantations stiff, water-logged, or alkaline soil and frosty localities should be avoided, care being taken to select places with soil which is light, porous, and not too moist. The site for the plantation should



FIG. 146. *Cassia auriculata*. Seedling $\times \frac{7}{8}$.
 a, seed, b-d, germination stages; e-g, early development of seedling.

be an open one, trees and bushes being removed if they are present. Direct sowing has given much better results than transplanting, and it has been found advantageous to plough up the land before sowing. The sowing may be done either broadcast or in lines : the latter method is considered preferable as it facilitates weeding, thinning out the seedlings, and loosening the soil. Lines 3 to 4 ft. apart produce a dense crop. In southern India June has been found to be the best month for sowing, except where the monsoon rains are heavy, in which case October is preferable. The seedlings should be thinned out during the first season where necessary ; weeding and cultivation of the soil, though not always essential, stimulate growth. Irrigation is not necessary except in an arid climate like that of Sind, where irrigated sowings are said to have produced a height-growth of 20. ft. in two years. Nevertheless, irrigation is sometimes carried out during the first two years in the normal climatic region of the plant, and this hastens growth. With suitable tending, but without irrigation, the plants should reach a height of about 4 or 5 ft. in the second year, or under favourable conditions more.

9. BAUHINIA, Linn.

This genus contains over thirty Indian species, of which the majority are climbers, more than a third being trees and shrubs. They are easily recognized from the two leaflets being united for a portion of their length, forming a bilobed palmately veined leaf. Although none of the trees are of great importance as producers of timber, the bauhinias are of special interest as being widely represented throughout the forests of India and being characteristic members of many different forest types. Some are useful indirectly, for example *B. purpurea* for stocking frosty blanks, *B. racemosa* for afforesting open places, *B. retusa* for clothing hill slopes.

Among the better known species five are described below in some detail, and these contain certain characters in common. They require care in transplanting, the roots being somewhat sensitive. The fruit forms rapidly and ripens soon after flowering, except in *B. racemosa*, which takes several months to ripen its pods. The pods dehisce as a rule on the tree, scattering the seeds : this is particularly marked in the climber *B. VahlII*, whose hard woody pods open with a crack in sunny weather and shoot the seeds to some distance. *B. malabarica* is an exception to the rule, the pods usually reaching the ground before dehiscing. The seed germinates readily, but in certain species (e.g. *B. malabarica* and *B. racemosa*) some of the seed may lie dormant for a year before germinating. It is of great advantage to successful reproduction if the seed becomes covered before germination, since the radicles of seeds germinating on the surface of the ground are liable to be eaten by birds or insects or to dry up before gaining a footing in the soil. Germination of the species studied is epigeous, but two species (*B. purpurea* and *B. variegata*) are interesting as showing a transition between hypogeous and epigeous germination.

The genus contains several climbers which are noxious to tree growth and require to be cut periodically in the forest. The best known is *B. VahlII*, W. and A., a gigantic climber sometimes reaching a girth of 4 or 5 ft. or even more ; its eradication is difficult, since when cut down it at once sends out from the base new shoots which grow at a very rapid rate.

at Bullawala, Dehra Dun, showed a mean girth of 7.7 in. and a mean height of 11 ft. 8 in. for *Cassia* as compared with 8.6 in. and 16 ft. respectively for sal.

The following figures give the results of measurements made in coppice coupes by Mr. C. M. McCrie in 1910 in Gorakhpur, United Provinces, together with measurements of sal coppice in the same coupes :

Cassia Fistula : rate of growth of coppice, Gorakhpur.

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DISTRIBUTION AND HABITAT. Common in the drier parts of the Indian Peninsula from Ajmer and the Jumna river southwards, covering large areas in the Deccan; also found in the dry zone of Upper Burma. It is common on dry stony hills in open places and in scrub forest; it occurs also on black cotton soil and on laterite near the sea-coast. It is naturally a species of hot dry regions, where the absolute maximum shade temperature varies from 100° to nearly 120° F., the absolute minimum from 33° to 55° F., and the normal rainfall from 20 to 50 in.

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Roots: primary root very long, terete, tapering, woody; lateral roots moderate in number, short to moderately long, distributed down main root. **Hypocotyl** distinct from root, 1–2 in. long, terete, tapering upwards, minutely pubescent when young. **Cotyledons** very shortly petiolate, foliaceous, somewhat fleshy, 0.6–0.8 in. by 0.5–0.7 in., sub-orbicular or broadly obovate, entire, green, glabrous. **Stem** erect, woody, glabrous, young parts green. **Leaves** alternate, compound, paripinnate, first 2–6 usually with 2 pairs of leaflets, subsequent leaves with 3–6 pairs or more. Stipules in young seedlings up to 0.25 in. long, linear or triangular acuminate, auriculate, green, pubescent. Rachis channelled above, sparsely pubescent. Leaflets shortly petioluled, with a filiform reddish gland at the base of each pair, 0.3–1 in. by 0.2–0.5 in., elliptical oblong, obtuse, mucronate, entire, terminal pair larger than remaining leaflets.

SILVICULTURAL CHARACTERS. This shrub does not stand shade or drip from overhead trees, and grows best in open places with an abundance of light. It is sensitive to frost, but stands drought well, growing readily on dry shallow soil. It prefers light porous soil; on water-logged ground or in soil containing an excess of moisture seedlings are apt to rot. The plant is avoided by goats and cattle, but plants cultivated near Dehra Dun were browsed by deer. It coppices well.

CULTIVATION. The plant has been frequently cultivated in various parts of India, and for the production of tan-bark it is worked as coppice. For tanning cow and buffalo hides the bark from shoots three to five years old gives the best results, whereas for tanning goat and sheep skins that of young shoots two years old is preferred: this refers to unirrigated plants. The rotation has thus to be fixed according to requirements.

For the formation of plantations stiff, water-logged, or alkaline soil and frosty localities should be avoided, care being taken to select places with soil which is light, porous, and not too moist. The site for the plantation should

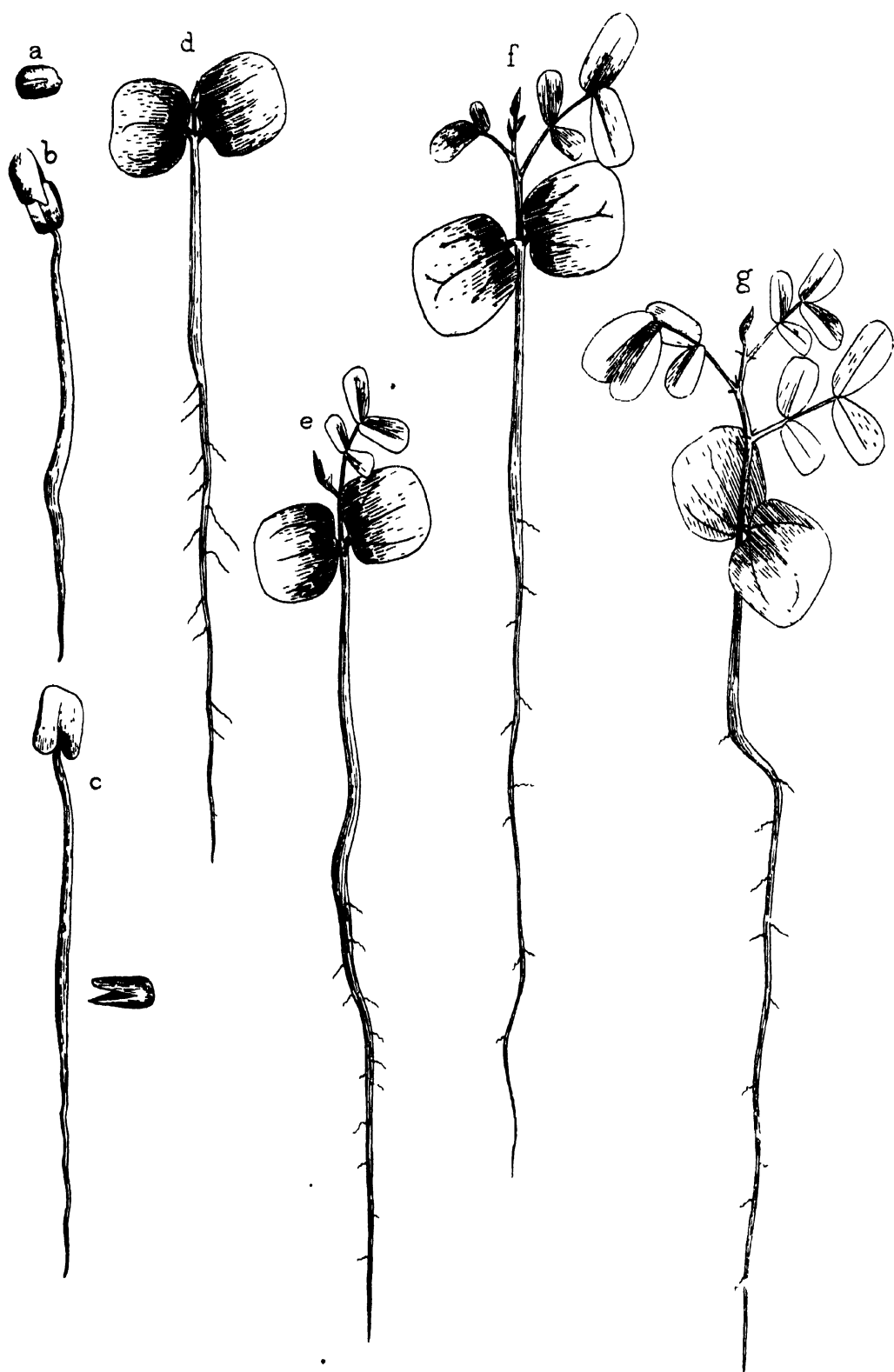


FIG. 146. *Cassia auriculata*. Seedling $\times \frac{7}{8}$.
 a, seed ; b-d, germination stages ; e-g, early development of seedling.

be an open one, trees and bushes being removed if they are present. Direct sowing has given much better results than transplanting, and it has been found advantageous to plough up the land before sowing. The sowing may be done either broadcast or in lines : the latter method is considered preferable as it facilitates weeding, thinning out the seedlings, and loosening the soil. Lines 3 to 4 ft. apart produce a dense crop. In southern India June has been found to be the best month for sowing, except where the monsoon rains are heavy, in which case October is preferable. The seedlings should be thinned out during the first season where necessary ; weeding and cultivation of the soil, though not always essential, stimulate growth. Irrigation is not necessary except in an arid climate like that of Sind, where irrigated sowings are said to have produced a height-growth of 20. ft. in two years. Nevertheless, irrigation is sometimes carried out during the first two years in the normal climatic region of the plant, and this hastens growth. With suitable tending, but without irrigation, the plants should reach a height of about 4 or 5 ft. in the second year, or under favourable conditions more.

9. BAUHINIA, Linn.

This genus contains over thirty Indian species, of which the majority are climbers, more than a third being trees and shrubs. They are easily recognized from the two leaflets being united for a portion of their length, forming a bilobed palmately veined leaf. Although none of the trees are of great importance as producers of timber, the bauhinias are of special interest as being widely represented throughout the forests of India and being characteristic members of many different forest types. Some are useful indirectly, for example *B. purpurea* for stocking frosty blanks, *B. racemosa* for afforesting open places, *B. retusa* for clothing hill slopes.

Among the better known species five are described below in some detail, and these contain certain characters in common. They require care in transplanting, the roots being somewhat sensitive. The fruit forms rapidly and ripens soon after flowering, except in *B. racemosa*, which takes several months to ripen its pods. The pods dehisce as a rule on the tree, scattering the seeds : this is particularly marked in the climber *B. Vahlia*, whose hard woody pods open with a crack in sunny weather and shoot the seeds to some distance. *B. malabarica* is an exception to the rule, the pods usually reaching the ground before dehiscing. The seed germinates readily, but in certain species (e. g. *B. malabarica* and *B. racemosa*) some of the seed may lie dormant for a year before germinating. It is of great advantage to successful reproduction if the seed becomes covered before germination, since the radicles of seeds germinating on the surface of the ground are liable to be eaten by birds or insects or to dry up before gaining a footing in the soil. Germination of the species studied is epigeous, but two species (*B. purpurea* and *B. variegata*) are interesting as showing a transition between hypogeous and epigeous germination.

The genus contains several climbers which are noxious to tree growth and require to be cut periodically in the forest. The best known is *B. Vahlia*, W. and A., a gigantic climber sometimes reaching a girth of 4 or 5 ft. or even more ; its eradication is difficult, since when cut down it at once sends out from the base new shoots which grow at a very rapid rate.

Species 1. *B. racemosa*, Lam.; 2. *B. malabarica*, Roxb.; 3. *B. retusa*, Ham.; 4. *B. purpurea*, Linn.; 5. *B. variegata*, Linn.

1. *Bauhinia racemosa*, Linn. Vern. *Jhinjeri*, *jhanjhora*, *makuna*, Hind. ; *Apta*, Mar. ; *Banne*, Kan. ; *Vattátthi*, Tam. ; *Ari*, Tel. ; *Palan*, Burm.

A small to moderate-sized deciduous (or evergreen ?) tree with a somewhat crooked bole, drooping branchlets, and small leaves broader than long, cleft nearly half-way down. Bark bluish black, rough with numerous deep vertical cracks, pinkish red inside, turning brown on exposure. The tree is of no importance for timber, but the bast yields a strong cordage fibre. Silviculturally it is of some importance as a common constituent of the drier types of forest and as a useful species for filling blanks.

DISTRIBUTION AND HABITAT. Throughout the greater part of India in deciduous forests of a dry type, ascending to 5,000 ft. in the western Himalaya; frequent in grassy blanks and open spaces, and common also on dry hills. In Burma it occurs on savannah lands and is fairly common in the dry zone associated with *Acacia Catechu*, *A. leucophloea*, *Pentacme suavis*, *Shorea obtusa*, *Terminalia Oliveri*, *T. tomentosa*, *Bridelia retusa*, *Diospyros burmanica*, *Buchanania latifolia*, *Zizyphus Jujuba*, *Odina Wodier*, *Cassia renigera*, *Phyllanthus Emblica*, and other trees.

In its natural habitat the absolute maximum shade temperature varies from 100° to 118° F., the absolute minimum from 30° to 55° F., and the normal rainfall from 30 to 85 in.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The old leaves are shed in the cold or early hot season and the new foliage appears in the hot season, sometimes before the old leaves have all fallen. The racemes of small creamy white flowers appear from March to June. The pods ripen in November–December and remain some months on the tree, falling towards the end of the hot season or early in the rains: they are indehiscent, 5–8 in. long, dark brown when ripe, thick, rigid, falcate, containing twelve to twenty seeds which rattle in the septate pods. The seeds (Fig. 147, *a*) are dark reddish brown, hard, smooth, shining, 0.3–0.4 in. by 0.18–0.25 in., with a hard fairly thick testa: about 220–250 weigh 1 oz. The seeds have a fairly high germinative power (58 to 95 per cent. in tests at Dehra Dun) and retain their vitality to some extent for at least one year. In order to collect the seed the pods should be plucked off the trees when thoroughly ripe, from January to March; they should then be hammered open and the seeds separated out.

GERMINATION (Fig. 147, *b–e*). Epigeous. The radicle emerges from one end of the seed and descends; the hypocotyl elongates by arching, and the cotyledons, enclosed in the testa, are carried up above ground, the testa falling with their expansion.

THE SEEDLING (Fig. 147).

Roots: primary root moderately long, wiry, flexuose: lateral roots moderate in number, fibrous: nodules present. *Hypocotyl* distinct from and thicker than root, 0.3–0.5 in. long, slightly compressed and more or less grooved down two sides, tapering downwards, green, glabrous. *Cotyledons* sub-sessile or very shortly petiolate, 0.9–1.2 in. by 0.5–0.6 in., foliaceous, somewhat fleshy, obliquely ovate elliptical, entire, green, glabrous. *Stem* erect, terete or slightly compressed, wiry, zigzag at the nodes, green, young parts minutely pubescent, soon becoming glabrous. *Leaves* simple, alternate.



FIG. 147. *Bauhinia racemosa*. Seedling $\times \frac{3}{4}$.
a, seed ; b-e, germination stages ; f-h, early development of seedling.

Stipules minute, subulate. Petiole 0.4–1 in. long. Lamina 0.6–1.5 in. by 1–2 in., broader than long, cleft nearly half-way down, mucronate, entire, subcoriaceous, glaucous beneath, darker above, glabrous, apices of lobes rounded, each lobe palmately 7- or 9-veined, with a straight midrib between the lobes.

The development of the seedling is rapid under favourable conditions, that is, particularly if weeding and watering are carried out. The young plant is of straggling habit, commencing to form strong side branches from the base at an early age; these side branches succeed each other in alternate succession up the stem and grow rapidly, those near the base attaining a length of over 3 ft. by the end of the first season in the case of vigorous plants. The stem and branches droop, their extremities often touching the ground. A long taproot is developed at an early age, and may attain a length of over 2 ft. in three months from germination. Growth ceases in November–December, and new growth commences in March; in the second season the growth usually starts with the elongation of the lower side branches, the main stem showing little or no growth until May or later (Dehra Dun). The leaves commence to fall in December and continue falling till May.

Seedlings have good power of pushing their way through grass and low weeds, but their development suffers until the weeds are overtopped; regular weeding has a marked effect on their growth. Drought is to be feared chiefly in the germinating stages in the case of seed lying on hard bare ground exposed to the sun. In frosty localities the seedlings are sometimes killed back, especially in grass, but have good power of recovery.

The following measurements of seedlings in experimental plots at Dehra Dun will give some idea of the rate of growth under different conditions:

Bauhinia racemosa : rate of growth of seedlings, Dehra Dun.

Condition under which grown.	Height and other particulars at end of season.			
	1st season.	2nd season.	3rd season.	4th season.
Weeded irrigated sowings	Maximum 4 ft. 2 in. (side branches up to 3 ft. 3 in. long)	Maximum 9 ft. 0 in. (dense crop, very vigorous)	Maximum 15 ft. 0 in. (maximum diameter 2½ in. at 2½ ft. from the ground)	
Unweeded irrigated sowings	Maximum 2 ft. 0 in.	Maximum 3 ft. 6 in. (chiefly under 1 ft. 6 in. among weeds)	0 ft. 2½ in.–3 ft. 9 in. (chiefly under 1 ft. 8 in.)	
Weeded unirrigated sowings	Maximum 3 ft. 0 in.	Maximum 3 ft. 2 in.	Maximum 7 ft. 7 in.	
Unweeded unirrigated sowings (i.e. natural conditions)	(1) Maximum 2 ft. 7 in.	Maximum 3 ft. 6 in.	0 ft. 5 in.–4 ft. 8 in. (chiefly under 2 ft. except where weeds scanty)	
	(2) Maximum 0 ft. 6½ in.	Maximum 1 ft. 3 in.	0 ft. 4½ in.–3 ft. 0 in.	Maximum 7 ft. 0 in.
Nursery-raised plants, transplanted with entire roots and stem	Maximum 1 ft. 2 in.	Maximum 3 ft. 6 in.	2 ft. 9 in.–4 ft. 2 in.	
Nursery-raised plants, transplanted with pruned roots and stem	Maximum 0 ft. 9 in.	Maximum 1 ft. 9 in.	0 ft. 10 in.–3 ft. 8 in.	
Weeded unirrigated line sowings with field crops	(1) Maximum 1 ft. 9 in.	Maximum 2 ft. 4 in.		
	(2) —	3 in.–3 ft. 10 in.		

These figures demonstrate the great value of weeding, whether irrigation be carried out or not.

SILVICULTURAL CHARACTERS. The tree is a light-demander, though sometimes found in slight shade. It is affected to some extent by frost, but has good power of recovery. In the abnormal drought of 1907 and 1908 in the forests of Oudh it proved to be decidedly hardy. The tree produces root-suckers and coppices well.

NATURAL REPRODUCTION. The pods fall towards the end of the hot season or early in the rains. If the seed be extracted from the pods germination commences with the early showers of May and continues for some time during the rains, some seed lying even until the second rains before it germinates. The pods being indehiscent the seeds do not escape for some time after the pods fall; this they do ordinarily through the pods rotting or becoming eaten by white ants, but in any case it is probable that under natural conditions most if not all of the seed fails to germinate until the rains of the following year. An important aid to successful germination is the covering of the seed by earth and débris, which often takes place under natural conditions during the period in which the seed lies on the ground before germinating. When germination takes place on the surface of the ground there is much mortality through the drying up of the radicle or its destruction by birds and insects. Natural seedlings are capable of struggling successfully through low weeds and grass, but their growth is kept back until the weeds are overtopped. In dry hot situations the seedlings tend to die back for a few years, finally starting upward growth when the root-system has established itself.

ARTIFICIAL REPRODUCTION. Experiments at Dehra Dun have shown that the best results are obtained by direct sowings in lines, the young plants being kept weeded and the soil being loosened from time to time. Line sowings with field crops, the crop employed being the lesser millet or *mandua* (*Eleusine coracana*), gave good results provided the lines were kept clear of crops to a width of 2 ft.

Transplanting can be carried out successfully with small nursery plants, the seed being sown in nursery drills not less than 9 in. apart in April or May and the seedlings transplanted during the first rains; the long taproot prevents successful transplanting later unless regular watering can be carried out, and experiments in pruning down the stem and taproot were only partially successful.

This is one of the species which have been raised by sowings in conjunction with field crops (sesamum, *tur* or *arhar*, and cotton) in the Amraoti forest division, Berar.¹

SILVICULTURAL TREATMENT. The tree is only of secondary importance, and is treated as an accessory species. Where a regular system is applied to the mixed forests in which it occurs the treatment usually followed is that of coppice or coppice-with-standards.

RATE OF GROWTH. So far as available statistics show, the rate of growth in high forest is slow. Sample plot measurements in the Siwaliks, extending over a period of twelve years, showed the following mean annual girth increments for the period:

Trees 12-24 in. in girth—0.21 in. (four measurements).

Trees 24-36 in. in girth—0.33 in. (four measurements).

¹ Ind. Forester, xxxvii (1911), p. 8.

As regards coppice, the following figures resulting from measurements made in 1910 by Mr. C. M. McCrie in the Ramgarh coppice coupes, Gorakhpur, United Provinces, indicate that the rate of growth for a time is fairly fast :

Bauhinia racemosa : rate of growth of coppice, Gorakhpur.

Age. years.	Mean height. ft.	Mean girth. in.
2	4.5	—
4	9.0	3.3
6	12.5	4.5
8	16.0	5.7
10	19.5	6.8
12	23.0	7.5

2. *Bauhinia malabarica*, Roxb. Vern. *Amlī*, *imlī*, *amlosa*, Hind. ; *Karmai*, Beng. ; *Shadlu*, Kan. ; *Atthi*, Tam. ; *Arām puli*, Mal. ; *Bwechin*, Burm.

A moderate-sized tree, evergreen or nearly so, with a bushy crown of dark green foliage ; leaves 2-3 in. long, broader than long, cleft about one-third of the length, acid to the taste, unlike those of *B. racemosa*, which they resemble somewhat otherwise. Bark rough, dark brown, exfoliating in long strips, pink to red inside. The wood is used only for fuel.

DISTRIBUTION AND HABITAT. Throughout the greater part of India and Burma, but not in the driest tracts, in deciduous forests usually of a moister type than those in which *B. racemosa* is found. It is a common accessory species in the sal forests of India, in the teak and lower mixed forests of Burma, and in the moist forests of western and southern India.

In its natural habitat the absolute maximum shade temperature varies from 95° to 110° F., the absolute minimum from 32° to 62° F., and the normal rainfall from 40 to 120 in. or more.

FLOWERING AND FRUITING. The dull whitish flowers, in small axillary racemes, appear from August to October, and the pods develop rapidly, ripening from January to March, and often hanging in large quantities on the trees. The pods are 7-12 in. long by about 0.75 in. broad, flat, flexible, many seeded, tapering gradually to a point. The pods either dehisce on the trees towards the end of the hot season or fall before dehiscing. The seeds (Fig. 148, *a*), of which about 320 weigh 1 oz., retain their vitality to some extent for one year.

GERMINATION (Fig. 148, *b-e*). Epigeous. The radicle emerges and descends, and the hypocotyl elongates by arching ; the cotyledons, enclosed in the testa, are raised above the ground, and the testa falls with their expansion.

THE SEEDLING (Fig. 148).

Roots : primary root moderately long, terete, tapering ; lateral roots moderate in number and length, fibrous. *Hypocotyl* distinct from and thicker than the root, 0.3-0.8 in. long, terete or slightly compressed, fusiform or tapering slightly upwards, sparsely covered with minute stiff hairs. *Cotyledons* : petioles 0.06 in. long, flattened above ; lamina 0.8-1.1 in. by 0.6-0.7 in., foliaceous, somewhat fleshy, oblong or elliptical, entire, sparsely covered with minute stiff hairs, 5-veined from the base. *Stem* erect, terete or slightly compressed, somewhat zigzag at the nodes, pubescent. *Leaves* simple, alternate, acid. *Stipules* 0.15 in. long, linear falcate, pubescent. *Petiole* 0.4-0.6 in. long, pubescent. *Lamina* 0.5-1 in. by 1-2 in., broader than long, cleft to

about one-third of the length, mucronate, base cordate, entire, glabrous, palmately 7-veined with a straight midrib between the lobes.

Under natural conditions the development of the seedling is slow, but if



FIG. 148. *Bauhinia malabarica*. Seedling $\times \frac{3}{4}$.

a, seed ; *b-e*, germination stages ; *f-h*, development of seedling during first season.

weeded and watered it grows more rapidly. Seedlings grown under natural conditions in grass at Dehra Dun had maximum heights of 0 ft. 4 in., 1 ft. 8 in., and 5 ft. 7 in. at the end of the first, second, and third seasons respectively. The seedling has good power of struggling through grass and low weeds, but

its growth suffers in the process and increases rapidly when the weeds are overtopped. The leaves fall about December–February, and new growth starts in March (Dehra Dun). The seedling is somewhat frost-tender in early youth.

NATURAL REPRODUCTION. The seeds are sometimes scattered through the pods dehiscing on the tree in dry hot weather, but perhaps more commonly they escape either through the dehiscence of the pod after reaching the ground or through the pod valves becoming eaten by white ants or rotting off. Germination commences early in the rains and continues for a time during the rainy season; many seeds lie ungerminated until the second rainy season. Germination is most successful on loose soil where the seed becomes buried; if it takes place on the surface of the ground the radicle is apt to dry up or to become eaten by insects or birds before it can penetrate the soil.

RATE OF GROWTH Little is known regarding the rate of growth of this species. Two trees measured for seven years in a sample plot in the Siwaliks showed the following growth:

1. Girth class 12 to 24 in.—mean annual girth increment for the period, 0.11 in.
2. Girth class 24 to 36 in.—mean annual girth increment for the period, 0.6 in.

3. *Bauhinia retusa*, Ham. Vern. *Kandla*, *semā*, *kurāl*, Hind.; *Nirpa*, Tel.

A moderate-sized tree, never quite leafless, with entire or emarginate coriaceous leaves 4–6 in. broad, somewhat broader than long. Bark 0.3–0.5 in. thick, dark brown, longitudinally cracked, pale pink inside. The bast yields a fibre and the cortex a clear gum, for which the trees are extensively tapped in some localities. Gamble says the wood is the best of those of the bauhinias, but is not much used. Silviculturally the tree is important in the outer Himalaya, as it covers the hill-sides at elevations intermediate between those at which many of the low-level species disappear and *Quercus incana* and its associates commence.

DISTRIBUTION AND HABITAT. Sub-Himalayan tract and outer Himalaya from the Beas to Nepal, Chota Nagpur, Orissa, Central Provinces (Raipur, Bilaspur, South Chanda, Bhandara, Balaghat), and the Circars. In the outer Himalaya it is gregarious at elevations chiefly between 3,000 and 4,500 ft., but on southern slopes it occasionally ascends to 6,000 ft., as below Naini Tal, where it is associated with *Quercus incana* and *Pinus longifolia*; it is also found in the Siwalik hills. According to Parker it occurs in the Jowlian reserve, Khanpur range, Hazara, but has not been collected between this and the Beas. It is always found on well-drained ground, on hill slopes or the sides of ravines. In the Himalayan and sub-Himalayan region it occurs mainly on shale, sandstone, and conglomerate. In Chota Nagpur it is common on the hills, especially on northern slopes, in Singhbhum and elsewhere. Haines says it is very common on quartzite along the Konar nadi, Hazaribagh, and that it is found on quartzite rocks near Deori, Bhandara, Central Provinces.

In its natural habitat the absolute maximum shade temperature varies from 95° to 115° F., the absolute minimum from 28° to 42° F., and the normal rainfall from 40 to 90 in.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The tree is never leafless : the old leaves fall during the hot season and the new bright green foliage appears in May and June, at which time the trees are conspicuous. The flowers appear from September to November, and the trees are then covered with masses of yellowish white blossom. The pods form rapidly, becoming a rich crimson colour before ripening ; the masses of crimson pods hanging amongst the rich green foliage give the trees a particularly handsome appearance from January onwards. The pods are 4–7 in. by 1·2–1·7 in., flat and hard ; they dehisce on the tree in June (outer Himalaya), the valves curling spirally and scattering the seeds. The seeds are dark brown, smooth, flat, about 0·5 in. in diameter.

SILVICULTURAL CHARACTERS. The silviculture of this tree has not yet been studied in detail. One particular requirement is a demand for perfect drainage. Otherwise its demands do not appear to be exacting, as it can grow on poor stony ground where many species could not survive.

NATURAL REPRODUCTION. The seeds, scattered towards the end of the hot season, germinate early in the rains, and, as in the case of other bauhinias, the establishment of the seedling appears to depend largely on the seed becoming covered with earth and débris, while new soil formed by landslips and erosion is very favourable to germination, and germinating seeds are sometimes found in quantity on such ground during the rains. These conditions commonly obtain on the hilly ground frequented by the tree, the flat seed lending itself to being covered with the loose earth washed down in the rains ; this may to some extent account for the gregariousness of the species in the outer Himalaya.

RATE OF GROWTH. Reliable statistics are wanting as regards the rate of growth of seedling trees. A cross-section 3 ft. 3 in. in girth in the silvicultural museum at Dehra Dun had 47 rings, giving a mean annual girth increment of 0·83 in.

Measurements made in 1916 in the Saitba coppice coupes, Kolhan, Chota Nagpur, show the following average rate of growth of coppice of *Bauhinia retusa* and sal respectively in a somewhat poor locality :

Bauhinia retusa : rate of growth of coppice, Saitba.

Age. years.	Mean height.		Mean girth at 4½ ft. from ground.	
	<i>Bauhinia retusa</i> . ft.	Sal. ft.	<i>Bauhinia retusa</i> . in.	Sal. in.
2	5·5	9·0	2·5	4·0
4	11·0	16·0	4·3	6·5
6	15·0	20·0	5·7	8·6
8	19·5	22·5	7·0	10·3
10	23·5	24·5	8·0	11·5
12	27·5	26·5	9·0	12·6
14	31·0	28·5	10·0	13·6

4. *Bauhinia purpurea*, Linn. Vern. *Khairwál*, *karár*, *koliár*, *kaniár*, Hind. ; *Atmatti*, Mar. ; *Sarúl*, *baswanwpada*, *kanchivála*, Kan. ; *Kanchan*, Tel. ; *Mahahlègani*, Burm.

A moderate-sized evergreen tree with a bushy crown ; leaves 3–6 in. long, somewhat longer than broad, cleft about half-way down. Bark dark grey or

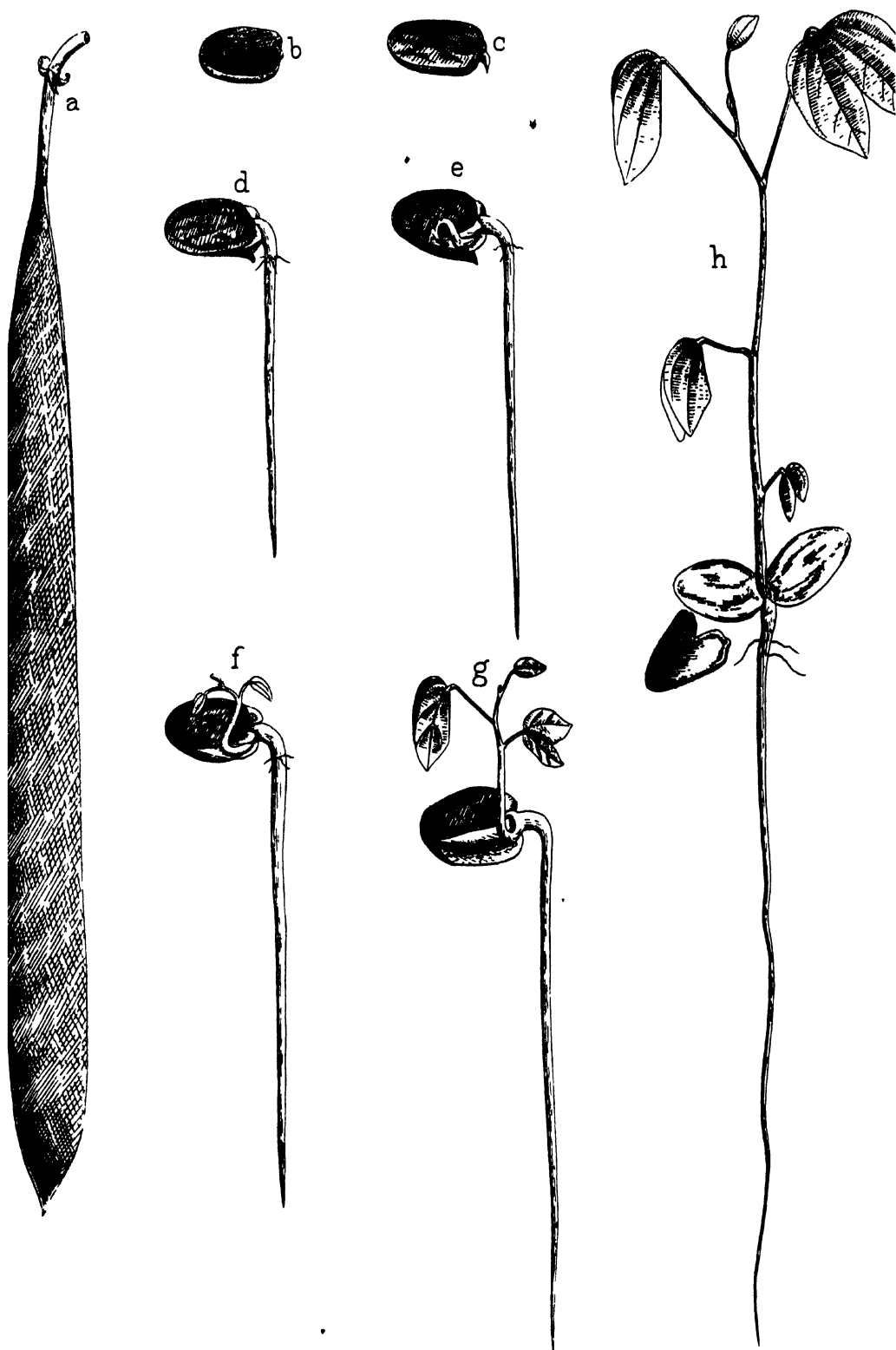


FIG. 149. *Bauhinia purpurea*. Seedling $\times \frac{3}{4}$.
 a, fruit ; b, seed ; c-f, germination stages ; g-h, development of seedling during first season.

brown, pink to pale yellow inside. The wood is used for agricultural implements and the bark for tanning.

DISTRIBUTION AND HABITAT. Common in the mixed and sal forests of the sub-Himalayan tract, ascending the outer hills and valleys to 4,000 ft., Assam and the Indian Peninsula; not indigenous in Burma. In its region the tree is characteristic of mixed deciduous forests, often of a dry type, occurring on hill slopes, in valleys, and along streams. Frequently cultivated for the sake of its handsome flowers. In its natural habitat the absolute maximum shade temperature varies from 100° to 115° F., the absolute minimum from 30° to 50° F., and the normal rainfall from 40 to 85 in.

FLOWERING AND FRUITING. The terminal paniced racemes of large purple, deep rose to lilac flowers appear amongst the foliage from September to December. The flowers are very fragrant, and are visited by numerous bees, by whose agency pollination is effected. The pods (Fig. 149, *a*) form rapidly, some attaining a fair length while the tree is still in flower: they ripen from January to March, and are then greenish purple, 6–12 in. by 0·7–1 in., flat, fairly thick, pointed, slightly falcate, with coriaceous valves, containing 10–15 seeds. The seeds (Fig. 149, *b*) are brown, compressed, 0·6 by 0·5 in. They germinate readily and have a high percentage of fertility, which they retain unimpaired for at least one year; tests at Dehra Dun with seed kept for 14 months showed a fertility of 100 per cent. The pods dehisce on the tree during the hot season, scattering the seeds.

GERMINATION (Fig. 149, *c-f*). Strictly speaking epigeous, but shows a transition between the hypogeous and epigeous form. The radicle emerges, while the plumule commences to grow and the young shoot to develop before emerging from between the cotyledons: the latter separate very slightly and the young shoot extricates itself by arching or bending as in hypogeous germination, but after its emergence the cotyledons, which become green, separate and are carried above ground on a short hypocotyl.

THE SEEDLING (Fig. 149).

Roots: primary root moderately long and thick, terete, tapering: lateral roots moderate in number, fibrous. **Hypocotyl** distinct from the root, 0·2–0·5 in. long, moderately thick, white or pale green, glabrous, subterranean or at ground-level. **Cotyledons** sub-sessile, 0·6–0·8 in. by 0·4–0·5 in., plano-convex, somewhat fleshy, oblong, apex rounded, base sagittate, green, glabrous. **Stem** erect, terete or slightly compressed, somewhat zigzag at the nodes, glabrous or young parts minutely pubescent; internodes 0·4–1·5 in. long. **Leaves** simple, alternate, at first small, becoming consecutively larger. **Stipules** 0·05 in. long, falcate. **Petiole** 0·3–1·3 in. long, finely pubescent. **Lamina** 0·3–1·5 in. by 0·3–1·5 in., about as broad as long, cleft to nearly half-way down, mucronate, apices of lobes acute, base cordate or truncate, entire, young leaves finely pubescent, palmately 7-veined with a straight midrib between the lobes.

The growth of the seedling is very rapid under favourable conditions. Nursery-raised plants at Dehra Dun, regularly weeded and watered, attained a maximum height of 3 ft. 9 in. in two months from germination. In one plot 17 nursery plants varied from 3 ft. 7 in. to 10 ft. 5 in. by the end of the first season; by the end of the second season they had a maximum height of 15 ft. 6 in., and were in flower. Under less favourable conditions the growth

is much slower. The season's growth ends about November, and new growth begins in February (Dehra Dun).

SILVICULTURAL CHARACTERS. The tree is a moderate light-demander. It is decidedly frost-hardy, as is proved by the fact that it may be found surviving on grass-lands subject to bad frosts, where all but the most frost-hardy trees fail.

NATURAL REPRODUCTION. The seeds germinate readily at the beginning of the rains, when numerous young seedlings may be found in the neighbourhood of seed-bearers. Where germination takes place on the surface of the ground, however, much mortality takes place owing to the drying up of the radicle if exposed to the sun. The survival of the seedlings is greatly facilitated if the seed becomes buried in loose earth before germination and the roots of the young plant are not exposed.

ARTIFICIAL REPRODUCTION. Experiments at Dehra Dun have shown that the best results are attained by line sowings kept regularly weeded : irrigation also has a marked effect on the growth. The seedlings are somewhat sensitive to transplanting, which has to be done with care. The seed should be sown in the nursery in April or May in drills 9–10 in. apart, and covered to a depth of about a quarter of an inch, regular watering and weeding being carried out. The seedlings appear in about 4–10 days, and can be transplanted while still of small size during the first rains. Transplanting with unpruned stem and roots should not be attempted during the second rains unless regular watering is possible for some time. A certain amount of success has been attained by transplanting after pruning the stem and taproot down to 2 and 9 in. respectively, but this checks the growth severely for a time.

5. *Bauhinia variegata*, Linn. Vern. *Kachnár*, Hind. ; *Kanchan*, thaur, Mar.

A moderate-sized deciduous tree with leaves 3–6 in. long, as broad as or broader than long, cleft about one-quarter to one-third down. Bark grey, with longitudinal cracks, pale pink inside. The wood is used for agricultural implements and the bark for tanning. The tree is extremely handsome when in flower, and is largely planted for ornament.

DISTRIBUTION AND HABITAT. The sub-Himalayan tract and outer hills and valleys from the Indus eastward, ascending to 5,000 ft., Assam, Burma, Chota Nagpur, Central Provinces, and other parts of the Indian Peninsula. Frequently cultivated for ornament. It is essentially a tree of the mixed deciduous forests, often of a somewhat dry type, and occurs frequently on hilly ground. It ascends some distance into the Himalayan valleys, and occurs gregariously on some of the outer hills up to 5,000 ft. on southerly aspects. In the Indian Peninsula it occurs chiefly on hilly ground, and in Burma it affects the drier types of mixed forest, entering the dry zone and ascending the hills to over 3,000 ft. In its natural habitat the absolute maximum shade temperature varies from 97° to 115° F., the absolute minimum from 28° to 45° F., and the normal rainfall from 40 to 100 in.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The leaves commence falling in November–December, and the tree is leafless or nearly so by March ; the new leaves appear in April and May. The large pink to purple or white flowers appear from February to April, chiefly on the upper leafless branches,

the lower branches often being still in leaf. The flowers are fragrant and are visited by bees, by whose agency pollination is effected. The pods (Fig. 150, a) form rapidly, ripening in May and June (northern India) : they are 6–12 in. by 0.7–1 in., hard and flat, with 10 to 15 seeds, and dehisce for the most part on the tree, scattering the seeds. The seeds (Fig. 150, b) are 0.5–0.75 in. by 0.5–0.7 in., nearly circular, flat, brown, with a somewhat coriaceous testa, 70–100 weighing 1 oz. ; they germinate readily and show a high percentage of fertility, which is retained to some extent for at least a year.

GERMINATION (Fig. 150, c–g) as in *B. purpurea*.

THE SEEDLING (Fig. 150).

Roots : primary root moderately long and thick, terete, tapering, whitish or light brown : lateral roots moderate in number, fibrous. *Hypocotyl* distinct from the root, 0.1–0.15 in. long, thick, tapering downwards, minutely pubescent or glabrescent, subterranean or at ground-level. *Cotyledons* sessile or subsessile, 0.8–1 in. by 0.6–0.8 in., plano-convex, somewhat fleshy, broadly elliptical or sub-orbicular, usually oblique, apex rounded, base slightly auriculate or sub-sagittate, entire, yellow or greenish, glabrous. *Stem* often arched during germination, soon becoming erect, grooved and angular, pubescent ; internodes 0.3–1.5 in. long. *Leaves* simple, alternate, the first one or two often small and abortive. Stipules minute. Petiole 0.3–1 in. long, pubescent. Lamina 0.4–0.9 in. by 0.8–1.6 in., broader than long, cleft to about one-quarter to one-third of the length, mucronate, apices of lobes often acute, entire, sub-coriaceous, glabrous above, slightly pubescent beneath, palmately 7- or 9-veined with a straight midrib between the lobes.

If weeded and watered the seedling develops rapidly. Nursery-raised plants at Dehra Dun attained a height up to 3 ft. 4 in. in two months from germination, with taproots up to 1 ft. 7 in. long and 0.5 in. thick. Eight nursery-raised seedlings in one plot varied from 3 ft. 7 in. to 7 ft. 10 in. in height by the end of the first season. Under less favourable conditions the growth is considerably less, natural seedlings usually attaining a maximum height of 1 ft. by the end of the first season. The season's growth ceases about November, and new growth commences in February (Dehra Dun).

NATURAL REPRODUCTION. The seeds, which are scattered before the beginning of the monsoon, germinate readily when the rains begin, and germinating seeds may be found in quantity round the trees. But unless the seed happens to become buried in earth and debris, or is sheltered from the sun, most if not all of the young plants may die off owing to the drying up of the radicle if exposed to the sun, while birds and insects also cause a good deal of mortality by eating off the radicles. The most favourable condition for the establishment of reproduction appears to be the presence of loose porous well-drained soil, in which in the first place the seed has a chance of becoming covered with earth, and in the second place the seedling develops sufficiently rapidly to overcome weed-growth.

ARTIFICIAL REPRODUCTION. The most successful means of raising the tree artificially is by sowing in lines in which the soil has been well loosened, followed by regular weeding and loosening of the soil. Unless regular watering can be carried out, transplanting is difficult except in the case of small plants during the first rains. The seed should be sown in May in drills 9–10 in. apart : the young plants usually appear in 4 to 10 days, and may be transplanted



FIG. 150. *Bauhinia variegata*. Seedling $\times \frac{1}{2}$.
a, fruit ; *b*, seed ; *c-g*, germination stages ; *h*, *i*, development of seedling to end of first season.

while still comparatively small during the first rains. Trees planted for ornament may be kept a second year in the nursery, but regular watering is necessary in the dry season following transplanting; in this case either the seedlings should be pricked out in the nursery during the first rains or the drills should be at least 12 in. apart, and the seedlings should be thinned out where necessary.

RATE OF GROWTH. The only authentic statistics relate to coppice coupes at Ramgarh near Dehra Dun, the following measurements having been recorded by Mr. A. F. Broun in 1886 (sal coppice measurements in the same coupes entered for comparison) :

Bauhinia variegata : coppice measurements, Ramgarh, Dehra Dun.

Age. years.	Mean height.		Mean girth.	
	<i>Bauhinia variegata</i> . ft.	Sal. ft.	<i>Bauhinia variegata</i> . in.	Sal. in.
8	18	16.3	7.5	8.3
8	20	13.2	6.0	7.1
9	13	16.0	7.0	8.6
10	10	11.9	4.0	5.9

SUB-ORDER III. MIMOSEAE

Genera 1. PROSOPIS, Linn.; 2. XYLIA, Benth.; 3. ACACIA, Willd.; 4. ALBIZZIA, Durazzini; 5. DICHROSTACHYS, DC.; 6. ADENANTHERA, Linn.; 7. PITHECOLOBIUM, Martius; 8. LEUCAENA, Benth.

1. PROSOPIS, Linn.

Species 1. *P. spicigera*, Linn.; 2. *P. juliflora*, DC.

1. *Prosopis spicigera*, Linn. Vern. *Jand*, Punjab; *Kandi*, Sind; *Khejra*, Rajputana; *Semru*, *sumri*, Guz.; *Shema*, *saunder*, Mar.; *Banni*, Kan.; *Jambu*, *parambe*, Tam.; *Jambu*, Tel.

A moderate-sized thorny tree, evergreen or nearly so, with light foliage and straggling rather slender branches armed with conical prickles. It does not ordinarily exceed a height of 40 ft. and a girth of 4 ft., the maximum attained being 50 ft. and 6 ft. respectively. The bole is usually short and is rarely straight; spines persist on the bole until it reaches a girth of about 1½ ft. Bark up to 1 in. thick, grey, rough with longitudinal furrows and transverse cracks. Wood very hard, heartwood dark brown; it makes excellent fuel and charcoal, and is used locally for various purposes. The pods contain a dry sweetish pulp, and are used as food for cattle.

DISTRIBUTION AND HABITAT. This tree occurs in the dry and arid regions of India, namely in Sind, the Punjab plains, Baluchistan, Rajputana, Guzerat, the Deccan, and the drier parts of southern India; it extends into Persia.

In Sind *Prosopis spicigera* is one of the principal species on the higher and older alluvium in the region of the Indus. Although found to a greater or less extent both in upper and in lower Sind, it may be considered to be the most characteristic species in the former just as babul (*Acacia arabica*) is in the latter: this is probably due partly to the greater intensity of frost in upper Sind, which is more harmful to *Acacia arabica* than to *Prosopis*, and partly to the fact that the duration of river inundations is longer and their

extent greater in lower than in upper Sind, the babul being favoured by these moister conditions. The occurrence of *Prosopis spicigera* marks one of the successive stages between that in which new alluvial ground is formed in the river-bed and the time when, owing to the receding of the river, this land is left high and dry above the reach of even abnormal river floods. The flood season of the Indus commences about the beginning of May, with the melting of the Himalayan snows, and the river continues to rise, with occasional interruptions, until July or sometimes later; thereafter it subsides gradually and reaches its winter level as a rule about the end of October. In the course of the annual floods much land is lost by erosion, while corresponding new land is won by accretion. The newest so-called *kacha* alluvium thrown up by deposits of silt becomes quickly covered with *Tamarix dioica* and *T. Troupii*, and a growth of *kanh* grass (*Saccharum spontaneum*): as the ground becomes more elevated *Populus euphratica* and *Acacia arabica* make their appearance, while later, when the land becomes elevated above the reach of all but abnormal floods, *Prosopis spicigera* becomes the prevailing species, having already gained a footing with the aid of the river floods and having survived after the preceding species have gradually disappeared. This, however, is not the final stage, for although its long taproot and its power of reproduction by root-suckers enable it to outlive its predecessors it is not strictly a desert species, and though it lingers for a long time on the older higher and drier alluvium it eventually gives place in the driest tracts to more typical desert species such as *Capparis aphylla*, *Salvadora oleoides*, and *S. persica*.

While often gregarious, particularly in upper Sind, *Prosopis* is frequently associated by single trees or small groups with the various species which precede it on the one hand and succeed it on the other. Thus, before it meets the desert species it may be found with *Tamarix dioica* and *Troupii* (sometimes in the form of moribund remnants), *Acacia arabica*, *Populus euphratica*, and *Tamarix articulata*, the largest species of *Tamarix*, which is characteristic of drier ground than the other two: again, on the older and drier alluvium *Prosopis* is commonly associated with the desert species already mentioned, with or without surviving individuals of the other species.

The soil on these alluvial tracts consists of varying mixtures of sand and clay. A special feature, indicative of deterioration of the soil through lack of surface drainage, is the presence of tracts of varying extent in which the soil is charged with an excess of sodium salts, these salts appearing as a white efflorescence on the surface of the ground. Where the soil becomes very saline *Prosopis*, in common with most other species, quickly dies out; on pure sand, also, it does not survive long.

In the Punjab *Prosopis spicigera* occurs throughout the alluvial plains from the Salt Range to the Sutlej river, but does not extend into the hills. By far the largest tracts are situated in the arid regions in the south-west of the province in the Multan and Montgomery districts. According to Mr. B. O. Coventry,¹ the area of these forests under the Forest Department in 1915 was about 3,500 square miles, of which about 2,700 square miles were in Multan, and about 700 square miles in Montgomery, the remainder being in the Lahore, Gujranwala, and Shahpur districts. There is little doubt that

¹ Ind. Forester, xli (1915), p. 307.

the area of forest was at one time far greater, and that it has been gradually curtailed by the extension of cultivation, a process hastened in recent times by the development of irrigation. This curtailment is still proceeding rapidly, and will continue to do so with the extension of irrigation, the natural dry forests giving place to cultivation and irrigated plantations, chiefly of *Dalbergia Sissoo*.

The five great rivers of the Punjab, of which the Indus is the chief, play an important part in the origin and the distribution of the *Prosopis* forests. These rivers, which are snow-fed, are liable to high floods when the Himalayan snows melt in the hot weather, and the process of annual flooding with attendant erosion and accretion proceeds in the manner already described for the Indus. The topography of the plains thus exhibits four main stages in the alluvial formation : (1) new alluvium in the river-beds ; (2) low land subject to inundation ; (3) higher ground beyond the reach of ordinary floods ; and (4) high so-called *bar* land forming the watershed between the rivers. The subsoil water-level varies from a few feet below ground surface in the low land near the rivers to as much as 100 ft. on the high *bar* land. The soil is a deep fertile loam with occasional hard pans of *kankar*, that is, concretionary calcareous deposits, a few feet below the surface, and with occasional unfertile tracts of saline soil locally known as *reh* or *kallar*. *Prosopis* regenerates on the low ground subject to floods, but not on the high *bar* land, and it owes its existence on the latter to the remarkable powers of survival due to its long taproot, which responds to the lowering of the water-level, and to its capacity for reproducing by root-suckers. Thus the conditions under which it is able to persist when once established are entirely unsuitable for its reproduction by seed, and it is further evident that this persistence may be of very long duration, perhaps, as Mr. Coventry remarks, for hundreds if not thousands of years.

On the high *bar* land *Prosopis* trees are as a rule somewhat scattered, and are usually associated with *Salvadora oleoides* and *Capparis aphylla*, while the two latter species often occur without *Prosopis*, which has gradually disappeared in course of time ; there are also frequently large blanks due to deposits of *kankar* or the presence of saline soil. Except for the tree growth the ground is bare of vegetation for several months in the year, though a fair crop of grass is produced during the rainy season. On the lower ground nearer the rivers the tree occurs gregariously in well-stocked crops ; here it is sometimes associated with *Tamarix* and with *Acacia arabica*.

In the Indian Peninsula the tree is not gregarious, but is scattered in open dry types of forest in association with *Acacia Catechu*, *A. arabica*, *A. leucophloea*, *A. eburnea*, *Chloroxylon Swietenia*, *Anogeissus latifolia*, *Zizyphus Jujuba*, *Z. Xylopyrus*, and other species. In some localities it occurs on black cotton soil with *Acacia arabica* and a few other kinds of trees.

In the most important areas of its distribution the climate is dry to arid, and is characterized by extremes of temperature, intense heat being a feature of the hot weather, while in the winter the thermometer may register a few degrees of frost. Within its region in Sind and the Punjab the absolute maximum shade temperature varies from 118° to 125° F., the absolute minimum from 25° to 40° F., and the normal rainfall from under 3 in. to about 25 in. or slightly over. In the Punjab plains it occurs most plentifully in the drier

regions where the normal rainfall is from 5 to 10 in. In Baluchistan it experiences lower temperatures than it does in Sind and the Punjab. In the Indian Peninsula it occurs in regions where the absolute maximum shade temperature varies from 105° to 115° F., the absolute minimum from 40° to 60° F., and the normal rainfall from 20 to 35 in.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The foliage becomes somewhat thin towards the end of the cold season. The spikes of small yellow flowers appear from March to May, after the new leaves. The pods ripen from June to August; they are indehiscent, 4–8 in. long, slender, contracted between the seeds, filled with a dry sweetish pulp, and contain 10–15 seeds. The seeds (Fig. 151, *a*) are 0.2–0.3 in. by 0.15–0.2 in., compressed, ovate oblong or rhomboidal, brown, smooth, hard, with a moderately hard testa. The seed retains its vitality for at least a year.

Recent experiments in the Montgomery district with seed from coppice-shoots 5–11 years old showed that such seed was sufficiently fertile and that seed from the younger shoots was as fertile as that from the older ones. Ordinarily the seed, if watered, germinates from one to two weeks after sowing. The seed is distributed partly by water, partly by birds, and partly by cattle and other animals, which eat the sweetish pulp of the pods and void the seeds.

GERMINATION (Fig. 151, *b–e*). Epigeous. The radicle emerges and the hypocotyl elongates by arching, carrying the cotyledons above ground when it straightens; as a rule the testa is carried up over the cotyledons, falling with their expansion.

THE SEEDLING (Fig. 151).

Roots: primary root long, thin, terete, tapering, wiry, yellow turning brown: lateral roots few, short, fibrous, distributed down main root: nodules present. **Hypocotyl** distinct from root, 0.8–1.4 in. long, terete, expanded in a ring at the base, white turning green, glabrous, smooth at first, soon becoming striate by cracks in the epidermis. **Cotyledons** very shortly petiolate, 0.5 by 0.4 in., elliptical ovate, apex rounded, base sagittate, foliaceous, somewhat fleshy, upper surface convex, lower concave, green, glabrous, 5-veined from the base, the two lateral veins very indistinct. **Stem** erect at first, soon branching and becoming straggling, zigzag at the nodes, wiry, glabrous, green or reddish, covered with prickles which are at first minute, later 0.1 in. long; internodes 0.2–0.3 in. long. **Leaves** alternate. Stipules 0.2 by 0.1 in., falcate, mucronate, green. First leaf pinnate, rachis 0.5 in. long, with occasional rudimentary or minute prickles, leaflets usually in five pairs, opposite, with very short petiolules, 0.2 by 0.1 in., obliquely oblong, mucronate, entire. Subsequent leaves bipinnate with one pair of opposite pinnae; common rachis 0.1–0.2 in. long, pinnae 0.3–0.6 in. with 4–6, later 7–8, pairs of leaflets similar to those of first leaf.

Under ordinary conditions the growth of the seedling is slow, though by irrigation and weeding more rapid development can be secured. In Sind, even in the case of irrigated sowings, the seedlings normally attain a height of only 6 in. to 1 ft. by the end of the first season. The seedling tends to assume a straggling growth, developing long side branches at the expense of height-growth. It forms a long wiry taproot, which by the end of the second season may attain a length of as much as 2½ ft. or more: this helps it to establish itself in the dry regions in which it grows. Young plants are somewhat sensitive to frost, and small weakly plants are liable to die back to ground-level owing to



FIG 151. *Prosopis spicigera*. Seedling $\times \frac{5}{8}$. †
 a, seed ; b-e, germination stages ; f-j, development of seedling during first season.

drought ; such plants, if they survive, are apt to assume for a time a bushy form owing to the development of new shoots from the lower portion of the stem. In the natural home of the tree, rats are often very destructive to young plants, gnawing them just below the ground-level ; in seasons of low inundation, when the rats become numerous, their ravages are worst. The leaves of seedlings fall during the cold season, the young plants being leafless for a time towards the end of that season.

The following measurements of seedlings grown in experimental plots at Dehra Dun (which, however, is outside the natural habitat of the tree) compare to some extent the growth under varying treatment :

Growth of *Prosopis spicigera* seedlings under varying treatment, Dehra Dun.

	Condition under which grown.	Height at end of season.		
		1st season.	2nd season.	3rd season.
	(1) In nursery, weeded and watered	0 ft. 1 in.-0 ft. 3 in.	Maximum 0 ft. 5 in. (side branches up to 1 ft. 7 in. long)	0 ft. 3 in.-0 ft. 8 in.
	(2) In nursery, weeded and watered	Maximum 0 ft. 6 in.	Maximum 1 ft. 2 in. (with several straggling branches)	
Adjacent.	(3) Broadcast sowing, irrigated, weeded	Maximum 0 ft. 8 in. (vigorous and numerous)	0 ft. 3 in.-1 ft. 9 in.	
	(4) Broadcast sowing, irrigated, unweeded	Maximum 0 ft. 5 in. (few, weakly)	1 ft. 1 in.-1 ft. 4 in. (only a few survived the weeds, but now over them and in good condition)	
	(5) Broadcast sowing, unirrigated, weeded	Maximum 0 ft. 4 in.	Maximum 1 ft. 0 in.	0 ft. 2 in.-0 ft. 9 in. (decrease due to damage by frost and drought).
	(6) Broadcast sowing, unirrigated, weeded	Maximum 0 ft. 7 in. (seedlings numerous)	0 ft. 2 in.-1 ft. 4 in. (seedlings numerous)	
	(7) Broadcast sowing, unirrigated, unweeded	Maximum 0 ft. 7 in. (seedlings few)	(all killed by frost or suppression)	

SILVICULTURAL CHARACTERS. The tree is a decided light-demander. Although the seedlings are sensitive to frost and drought, older plants are very drought-resistant and stand frost better than *Acacia arabica*. Although it resists ordinary frosts within its habitat, it suffered somewhat in the Punjab plains during the abnormal frost of 1905. A most important characteristic of the tree is the extremely long taproot which it develops ; this enables it to retain possession of the ground, in the dry regions which it inhabits, by obtaining its water-supply deep down in the subsoil. Gamble ¹ mentions a specimen of a taproot, exhibited at Paris in 1878, which was 86 ft. in length, and had penetrated vertically for 64 ft. Mr. Navani ² mentions a taproot which was dug up in Sind and found to measure 117 ft. in length.

¹ Man. Ind. Timbers, 1902, p. 288.

² Revised Working Plan for the Jerruck Forest Division, Sind, 1915.

The tree coppices well up to a moderate age, but old trees usually coppice badly or fail to coppice. Prolonged inundation is harmful to coppice, and it is therefore advisable to cut the stools high in places liable to be flooded for long; otherwise the coppice grows vigorously on irrigated forest land. In dry localities the stools sometimes become covered with the mounds of white ants, but although the growth of the coppice is thus checked, growth is carried on by root-suckers produced around the stump.

The tree reproduces freely by root-suckers, a form of reproduction which is of great importance in enabling it to survive long after its original associates have disappeared, and to reproduce itself freely after conditions have become impossible for reproduction by seed. Although the production of root-suckers is apparent everywhere, it seems to be most active where the water-level is comparatively near the surface; on high ground where the water-level is deep root-suckers appear for the most part close round the parent stem, and develop slowly. Felling, particularly if the stumps are grubbed out, appears to stimulate the production of suckers: on land cleared for cultivation the roots left in the ground reclothe the area with a flourishing crop of suckers which require to be dug out again. Fires in the grassy areas of riverain tracts also stimulate the production of suckers.

In some localities the tree is pollarded for camel and goat fodder: this induces rot, which spreads down into the bole, and it also frequently causes the appearance of numerous epicormic branches. The tree is readily browsed by camels and goats, and in areas open to goat browsing young plants assume a bushy growth, while a similar bushy growth often surrounds the bases of the trees owing to the browsing down of the root-suckers around them.

NATURAL REPRODUCTION. Experiments at Dehra Dun showed that under natural conditions the seed germinates at different times during the rainy season after heavy rain, some lying ungerminated until the second season. Germination and the establishment of the seedling are greatly assisted if the seed becomes slightly covered with soil; seeds washed into heaps in loose alluvial sand were found to germinate in quantity. If the seed germinates on the surface of the ground the radicle is apt to be eaten by insects or to dry up if there is insufficient moisture. In the dry weather following the rainy season there is much mortality among seedlings which have not succeeded in establishing themselves thoroughly.

In Sind and the Punjab natural reproduction by seed is confined almost exclusively to moist depressions and other places not far from the rivers, where the seedlings obtain occasional surface water and where the proximity of the subsoil water-level to the surface ensures soil moisture sufficient to enable the seedlings to establish themselves. This question of soil moisture appears to be all-important, for whereas on the lower ground near the rivers promising crops of *Prosopis* establish themselves from seed, on the high and dry ground away from rivers seedling reproduction is almost entirely absent, and the species has to depend on its remarkable power of reproduction by root-suckers to maintain its existence in these dry tracts. Here, although the seed may germinate successfully, the seedlings are unable to survive the drought.

In the riverain areas the young plants appear to resist suppression better than *Acacia arabica*, and are often found making their way through a fairly dense growth of grass where the latter species fails to establish itself.

ARTIFICIAL REPRODUCTION. Various experiments carried out at Dehra Dun have shown that transplanting cannot be relied upon, but that direct sowings are successful if the seedlings are kept free from weeds and the soil is periodically loosened. Transplanting was tried both in the first and in the second rainy season, with entire as well as with pruned roots and stem, but failure resulted in each case.

In the dry parts of the Punjab plains, attempts have repeatedly been made to raise plantations by direct sowing without irrigation, but failure has resulted in every case, since the plants, just as in the case of natural seedlings, are unable to resist the drought. On the other hand, sowings artificially irrigated have proved quite successful, as in the case of the portion of the Changa Manga plantation known as the 'Jand extension', formed about the year 1885, and now a flourishing plantation of *Prosopis* several hundred acres in extent (see Fig. 152).

In Sind the tree has been successfully raised by sowings in conjunction with cereal crops on irrigated land. It has also been raised successfully by sowings on land which is subject to occasional floods but is too dry to support *Acacia arabica* permanently: these sowings require to be watered thoroughly during the first year, after which occasional watering is usually sufficient until the plants are established. Sowings of *Prosopis* in conjunction with field crops are carried out as a rule on the higher land above the reach of river floods, the lower land being devoted to the raising of the more valuable *Acacia arabica*. On these higher lands the system usually followed is to sow strips of *Prosopis* 4 ft. wide, with intervening strips 20 ft. wide sown with field crops. Irrigation is carried out by means of Persian wheels. Cultivation along with irrigation continues for two years; during the third year there is no cultivation of field crops, but irrigation is continued under agreement with the cultivator. After the third year the seedlings require no attention, but have to be protected against browsing animals. The field crops are the irrigated *kharif* crops sown in June together with the tree seeds and reaped in November; the crops commonly cultivated are the two millets *bajri* (*Pennisetum typhoideum*) and *jowari* (*Sorghum vulgare*), and sometimes sesamum, chillies, or other crops. The crops are irrigated from June to October. The field crops are assessed to revenue, and the cultivation is carried out under a regular agreement by which the cultivator is bound to protect the young plants from browsing and other injury during the three years in which they are under his care.

An experiment, which appears to have been successful, in planting up saline land with *Prosopis spicigera* and *Acacia arabica*, is described under the latter (p. 440).

SILVICULTURAL TREATMENT. It will be apparent from what has been said above that seedling reproduction is not obtainable in the plains of Sind and the Punjab except in riverain areas subject to occasional floods: hence throughout the higher tracts any system involving the retention of seed-bearers is out of the question.

In the Punjab the system in operation is simple coppice, and the rotation

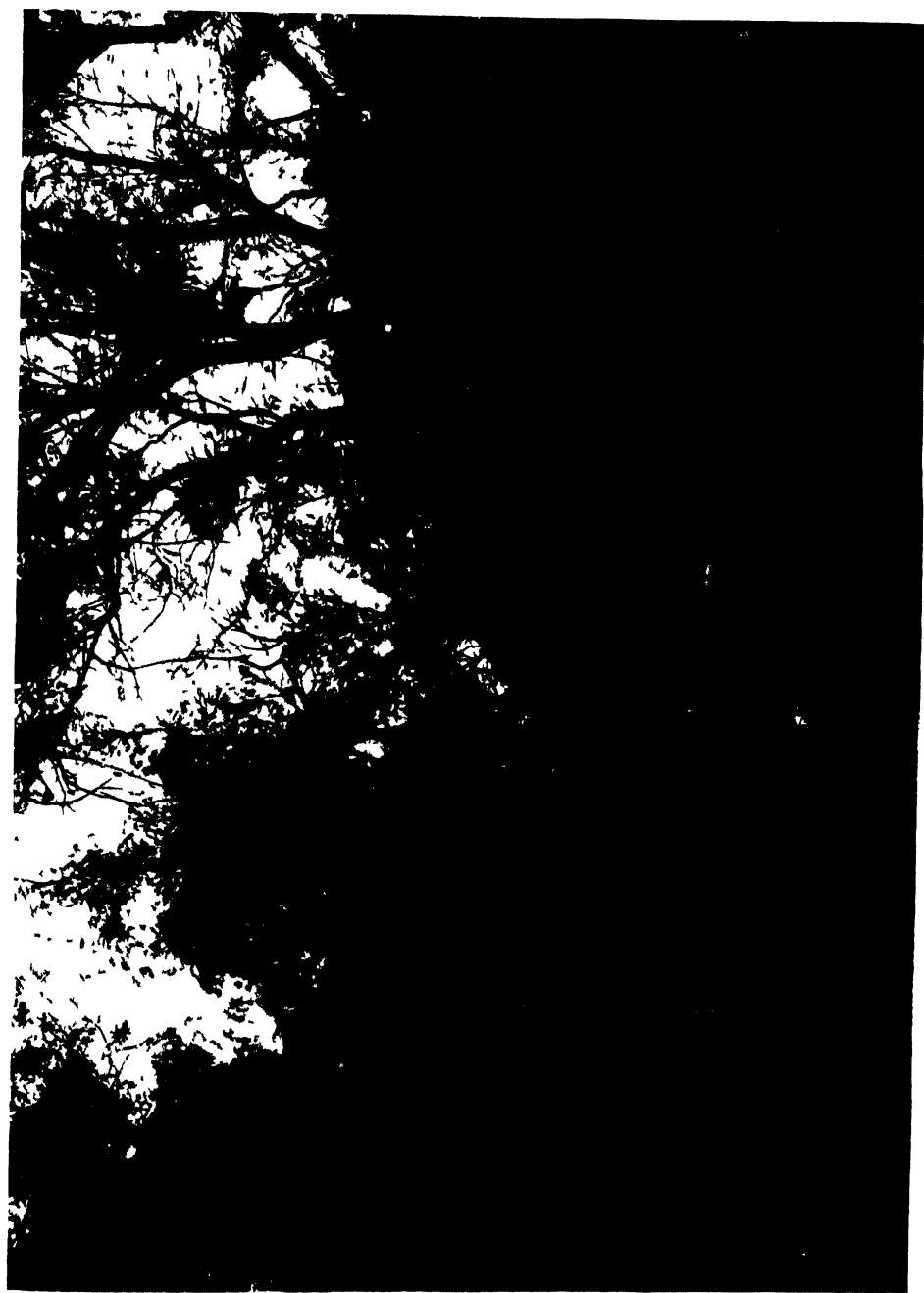


FIG. 152 *Prosopis spicigera* plantation about 40 years old. Changa Manga, Punjab



FIG. 153 *Xylia dolabriformis* Burma.

commonly adopted is thirty years. In Sind the treatment followed, which is based primarily on the requirements of the principal species, *Acacia arabica*, is that of clear-felling with natural reproduction on the riverain alluvium, supplemented where necessary by artificial sowing, often with the aid of field crops; these sowings, as applied to *Prosopis spicigera*, have been described above. At one time a rotation of fifteen years was adopted, but as this was found to be too short it was raised subsequently to thirty years, which is the rotation prescribed in the more recent working plans. In the Sind coupes, reproduction of *Prosopis* is secured also by root-suckers and coppice-shoots.

It is many years since the stimulation of reproduction by root-suckers became the subject of observation and experiment in the Punjab. In 1881 'Punjabi',¹ recording his observations in the case of land cleared for cultivation where the stumps were respectively left in the ground and grubbed out, notes that in the latter case the resulting root-suckers were stronger and more numerous than in the former, and ascribes this in part to the fact that water lodges in the holes left after grubbing out the stumps and tends to keep the surrounding soil moist: these observations were subsequently confirmed by experiments made on forest land. The grubbing out of the stump and upper portion of the taproot, apart from its effect in stimulating the production of root-suckers, has the advantage of providing a considerable quantity of fuel and thus increasing the yield. The question of sucker reproduction is again alluded to in 1892 by Mr. C. F. Elliot,² who writes: 'It is some years since in the Punjab we recognized that the regeneration of *Prosopis spicigera* in the bar forests depends chiefly on root-suckers; at all events, that any improvement in the way of filling up blanks will be accomplished in this way and not by seed. . . . It is well known that these shoots from the roots of trees of which the stumps and main roots even have been dug out on the compartment lines are almost impossible to kill: year after year they have to be cleared away to keep the lines open.'

RATE OF GROWTH. Seedling trees. The growth of the seedling for the first few years is slow, but subsequent growth up to an age of about forty to fifty years is fairly rapid, particularly on land which is subject to periodical floods. In the original working plan of the Jerruck division, Sind, it is estimated that an average diameter of 10 in. is attained in 30 years.³ In the Naushahro division, Sind,⁴ countings of annual rings on stumps of seedling stems in riverain forest gave 3.1 in. diameter in six years, 5.1 in. diameter in eleven years, and 6.6 in. diameter in fourteen years. In partially inundated areas the growth was faster, namely 6 in. diameter in nine years, and 7.5 in. diameter in fourteen years.

Coppice-shoots. Mr. B. O. Coventry⁵ estimates that coppice-shoots in the Punjab attain a height of about 30 ft. in fifteen years, with a girth of 2 to 3 ft. in good localities, and that the out-turn of fuel per acre varies from 100 to 1,000 cubic ft. and averages 300 cubic ft. stacked. The following measure-

¹ Ind. Forester, vi (1880-1), p. 327.

² *Ibid.*, xviii (1892), p. 305.

³ Working Plan for the Jerruck Division, Sind, A. C. Robinson, 1899.

⁴ Working Plan for the Forests of the Naushahro Division, Sind, A. C. Robinson, 1900.

⁵ Ind. Forester, xli (1915), pp. 310-11.

ments of vigorous and fairly vigorous coppice-shoots in Multan are recorded by Mr. A. L. McIntire : ¹

Prosopis spicigera : coppice measurements, Multan.

Age. years.	Diameter. in.	Out-turn of thick wood over 2 in. in diameter per stool. cubic ft. stacked.
5	1 to 2.5	—
10	3 to 5	1 to 10, av. 4
15	5 to 7 or 8	6 to 18, av. 10
20	6 to 9 or 10	10 to 30, av. 20

Experimental coppice fellings in the Montgomery district were carried out in 1912 in different months from April to November; measurements made on January 10, 1915, showed that shoots obtained from trees felled from April to August (i.e. aged two years five months to two years nine months) varied in height from 6 ft. to 12 ft. 6 in., whilst those from trees felled from September to November (i. e. aged two years two months to two years four months) varied in height from 4 ft. to 7 ft. 8 in.²

Measurements made in 1899–1900 in annually inundated riverain coppice coupes in the Naushahro forest division, Sind, gave the following results : ³

Prosopis spicigera : measurements of riverain coppice, Naushahro, Sind.

Forest.	Age 3 years.		Age 4 years.	
	No. of stems measured.	Mean girth at 1 ft. from ground-level. in.	No. of stems measured.	Mean girth at 1 ft. from ground-level. in.
Mohbat Dero . . .	29	5.9	39	9.5
Bhour . . .	60	6.2	81	9.5
Bhorti . . .	25	5.9	34	9.5

In the Jerruck division of Sind it is estimated that coppice-shoots 4–8 in. in diameter are produced in fifteen years.⁴

The following measurements, made in 1901–2, of 2,073 coppice-shoots in the Sukkur division of Sind, show the average rate of growth in riverain and dry forests respectively : ⁵

Prosopis spicigera : coppice measurements, Sukkur, Sind.

Age. years.	Mean diameter.	
	Riverain forests. in.	Dry forests. in.
2	1.77	1.20
3	2.48	1.72
4	3.65	2.43
5	4.25	2.89
6	5.17	3.51

¹ Working Plan for the South Kabirwala and Mailsi Forests, Multan, 1899.

² Punjab Forest Conference Proceedings, 1915, p. 17.

³ Working Plan for the Forests of the Naushahro Division, Sind, A. C. Robinson, 1900.

⁴ Working Plan for the Forests of the Jerruck Division, Sind, A. C. Robinson, 1899.

⁵ Working Plan for the Forests of the Sukkur Division, Sind, A. C. Robinson, 1903.

The following coppice measurements in Baluchistan are recorded in the Forest Report of that province for 1915-16 :

Prosopis spicigera : coppice measurements, Baluchistan.

Age. years.	Maximum height.		Forest.
	ft.	in.	
4	5	8	Gullushahr
8	20	1	Abdulla Kheli
9	22	2	—
10	22	0	—
11	22	10	—

2. *Prosopis juliflora*, DC. Var. *glandulosa*, Sarg. Syn. *P. glandulosa*, Torr.; *P. pallida*, H. B. and K. Mesquit bean.

This species is very variable : the variety *velutina*, Sarg., is said to be the more useful timber variety, the tree reaching a height of 50 ft. and a diameter of 2 ft. (cf. R. S. Hole in *Ind. For. Records*, vol. iv, pt. iii). *P. juliflora*, DC., the typical variety (or species) is a small evergreen tree, usually unarmed ; it is cultivated in northern India, but not extensively. Var. *glandulosa*, Sarg. (*P. glandulosa*, Torr.), is a small or moderate-sized deciduous tree armed with stout scattered axillary thorns : it appears to have been first introduced into India in 1877 from seed obtained through Kew, and in some of the drier parts of India has proved of great importance for afforestation work, for which purpose it deserves further attention. It is recommended for planting shifting sands in dry localities. It is also a useful source of supply of fuel, of famine fodder, and of food for man in times of scarcity, the pods being sweet and edible.

Its natural distribution, according to Bentham,¹ is 'west tropical and sub-tropical North and South America ; very abundant from Buenos Ayres and Chile, along the Andes, to Mexico and Texas, and frequently planted'. In North America it is 'one of the characteristic trees of the lower Sonoran Zone, an area where the conditions as to rainfall and climate range from arid to semi-arid, that is, the rainfall varies from less than 10 to about 25 in. per annum'.²

● In Jamaica the tree is known as 'cashaw', and is described as 'an admirable tree (often attaining a height of 40 to 60 ft.) to grow in dry gravelly soil, and in situations where rain does not fall for months together. It is fast growing : the timber is excessively hard and of a remarkably durable character. It is used for making knees of boats and all work requiring strength and tenacity. Posts of cashaw in wire fences last longer than any other, and are in great request for that purpose. . . . The pods are of a sweetish succulent character eagerly sought for by cattle : indeed in some parts of this island during droughts they subsist largely on them.'³

In India it has succeeded admirably in dry regions, reproducing sometimes in profusion by seed and by root-suckers : in damp localities, however, the seedlings are apt to die off in the first rains, being susceptible to an excess of moisture. In Sind it has proved a most useful sand-binder, and has been grown there since 1878. It may be seen growing in profusion about Miani

¹ *Mimoseae* in Trans. Linn. Soc., vol. xxx, 1874.

² U. S. Dept. Agric. Bull. 16, J. G. Smith, 1899, p. 18.

³ Ind. Forester, x (1884), p. 293.

near Hyderabad. For many years inroads of drifting sand gave much trouble in this place, but it has reproduced naturally over the Miani plain through seed distributed by goats, which eat the pods; as a result it has fixed the sand and has formed an efficient screen against further inroads of drifting sand. It has also done well in Baluchistan, where it has been found to resist drought admirably.

In northern India the seed ripens in May and June. Seedlings can best be raised in flower-pots, several seeds being sown in each pot. When about 4 in. high they are transferred singly to small pots, and planted out in the monsoon, about August, after a good fall of rain. Direct sowings are also successful.

Mr. R. N. Parker has published the following interesting note on the tree in the Punjab: ¹

'One striking peculiarity about the plant is that wherever large specimens are seen in dry and arid districts, natural seedlings are almost sure to be found in abundance in the immediate neighbourhood. The tendency of *P. juliflora* to spread naturally may be seen on the unirrigated strip of land between the canal and the plantation at Changa-Manga. Here the rainfall averages 15 inches and the strip of land referred to carries a sparse growth of the trees which were found in this district before the plantation was made, i. e. *Prosopis spicigera*, *Capparis aphylla* and *Salvadora oleoides*. A few trees of *P. juliflora* were planted some years ago in this strip and they are spreading rapidly, the seedlings being in places so dense that it is difficult to walk through them. Cattle graze here daily, but plants within easy reach show no signs of having been browsed. Seedlings of the indigenous trees it may be remarked are conspicuous by their absence. *P. juliflora* keeps to the unirrigated ground and shows no inclination to spread into the plantation.

'In Khushalgarh, in what once was the compound of a P.W.D. building but which now is the most accessible portion of the village grazing ground, there are two *P. juliflora* trees about 2 ft. in girth and 25 ft. high. A few root-suckers of *Capparis aphylla* badly browsed by goats and a soft sandstone rock describes the growing stock and soil of the surrounding waste. The rainfall is, I believe, about 18 inches. In spite of these unfavourable conditions, seedlings of *P. juliflora* are plentiful around the large trees and extend some distance away into the village waste.

'In the Pabbi reserve *P. juliflora* has been successfully used in reboisement works and has made considerably faster growth than *Acacia modesta*, with which it has as a rule been mixed. Regeneration of *P. juliflora* is frequent in the Pabbi reboisement area, whereas natural seedlings of the indigenous trees are difficult to find. *P. juliflora* was tried many years ago at Gujranwala. I have not seen the original trees, but along the railway line all the way from Gujranwala to the Pabbi Hills natural seedlings of *P. juliflora* may be seen at frequent intervals. *P. juliflora* has certainly come to stay in the Punjab and it is likely to be a common tree in all the drier districts in time.

'I have grown *P. juliflora* on a small scale almost every year since 1906, mainly without much success, but as failures often teach us more than success, I mention some of them. In 1906-07 I tried *P. juliflora* at Nurpur, district Kangra. The plants grew well as long as they were in pots, but on being planted out they did badly and none were left when I visited Nurpur in October 1912. In Nurpur the rainfall is 67 inches, but the plants were tried in a dry well-drained place. In the winter of 1907-08 I planted some plants in a hedge of Agaves at Phillaur. The plants were not watered at all, but I saw them on the 30th June, 1908 (the rains broke next day), and found them all doing

¹ Ind. Forester, xxxix (1913), p. 320.

well. I looked for these plants when I next visited Phillaur in July 1912, but found very few left, and these had made poor growth. A few hundred yards off there was a natural seedling of *P. juliflora* growing in a field, and the growth made by this plant in the four years 1908-12 was very marked. The rainfall in Phillaur is about 30 inches. In 1909 I tried *P. juliflora* in a grassy blank in one of the scrub forests in Hazara. I saw the sowings about a year later and found that the plants had made very poor growth and gave little promise of surviving. In this case the rainfall was 30-40 inches.

'The spread of *P. juliflora* over grass-lands in parts of America has been attributed to the stocking of the country with cattle, which graze down the grass and weaken it, and thus enable the tree to compete successfully against it. In the cases of failure with *P. juliflora* mentioned above there was a fairly heavy grass growth and protection from grazing, and it seems that this may have been responsible for the bad results. The rainfall could not have been responsible except perhaps indirectly by favoring the growth of other plants, as the natural seedling in Phillaur showed. This seedling was in a place where grass and jungle were kept down by cattle. Cattle and even goats seem to do little harm to *P. juliflora*, and I have often been surprised to see the leaves untouched, although within easy reach of cattle and at a time when there is little green fodder available.

'As regards frost-hardiness, I have seen seedlings pass through a winter at Abbottabad (4,000 ft.) uninjured, so that it may be regarded as quite hardy anywhere in the plains of India.

'The habit of *P. juliflora* is peculiar: most of the trees and all the natural seedlings I have seen branch at ground level, giving several crooked branches. . . . There is, however, an erect form, and the two big specimens in Khushalgarh had an upright habit not unlike that of *Acacia arabica*. This form, however, is not constant, as the seedlings from the Khushalgarh trees all showed the usual crooked habit.

'As regards the rate of growth of *P. juliflora*, G. B. Sudworth says in "Forest Trees of the Pacific Slope": "The tree is unquestionably long lived, though of exceedingly slow growth. Trunks 10-12 inches in diameter are from 100 to 125 years old, while the larger trunks occasionally found are likely to be very much older." This does not apply to the tree in India, as it has only been introduced some 35 years, and specimens 6-8 inches in diameter are not infrequent. . . .

'As a drought-resister I know of no tree to equal *P. juliflora*. It has been used with success to clothe some old brick-kiln mounds in the Government Agri-Horticultural Gardens, Lahore. The average rainfall in Lahore is 19 inches, and of this a large portion usually falls in heavy showers on one or two days in the year and runs off the steep slopes of the mounds so that the trees have to manage with considerably less than 19 inches of effective rain. Two years in succession of deficient rain has caused some of the plants on the top of the mounds to lose the tips of their shoots, but although there must be fully 100 specimens I have not seen a single one that has died of drought. On the very top of one of these mounds a sowing was made in 1911. The seedlings were not watered, and the rainfall in 1911 and 1912 was 13 and 14 inches respectively. When I last saw the place about a month ago, a good many plants were left. The place is much frequented, and the survivors all showed signs of having been trodden on, so that it is quite likely that those which died, died from having been trodden on and not from deficient moisture. Mr. Brown, Superintendent of Farms, N.-W. F. Province, tells me he has *P. juliflora* growing luxuriantly on the crest of a dry bank near Peshawar. The plants were planted in February 1911, and were not watered; the rainfall in 1911 amounted to 13 inches, and to 8 inches in 1912. The ability of this plant to withstand drought is astonishing, especially as it comes into leaf early in April and remains green right through the hot weather.

' . . . Any one who has collected seeds of Indian Acacias or Albizzias must have noticed the large proportion attacked by insects. With *Acacia modesta* in the Punjab it is not uncommon to find fully half the seed crop destroyed by weevils. In the case of *P. juliflora* seed collected in India, I have never seen a single seed attacked. To this is perhaps largely due the profuse reproduction of *P. juliflora* in suitable localities as compared with the indigenous trees. During the past 18 months I have received several consignments of *P. juliflora* seed from Mexico, and in each case found a very large proportion of the seed destroyed by weevils. It is evident that *P. juliflora* on being brought to India has left its natural enemies behind. The publicity given to the merits of this tree may perhaps lead to fresh consignments of seed being imported from America, and if this is done, care should be taken to see that the weevils are not introduced too. As seed is produced in abundance in India there is no need to import it from America, unless the object be to obtain other varieties than var. *glandulosa*. Last year over 60 maunds of seed was collected in the Pabbi Reserve, and several maunds could be collected annually in Lahore or Changa-Manga.'

2. XYLIA, Benth.

Species 1. *X. dolabriformis*, Benth.; 2. *X. xylocarpa*, Roxb.

1. *Xylia dolabriformis*, Benth. Ironwood of Burma, pyinkado. Vern. *Pyinkado*, *pyin*, Burm. (Fig. 153.)

A very large deciduous tree. Leaves bipinnate with one pair of pinnae, each pinna with two to six pairs of leaflets. Bark thin, yellowish or reddish grey, fairly smooth, exfoliating in irregular rounded plates. Wood reddish brown, very hard, heavy and durable, extensively used for house and bridge construction and for railway sleepers; it is one of the most important timbers in Burma.

Under favourable conditions the tree reaches a height of 120 ft. and a girth of 12 ft. or more, but on poor ground it is stunted.

DISTRIBUTION AND HABITAT. Throughout the greater part of Burma and Arakan, ascending to 3,000 ft. In the Irrawaddy valley it extends as far north as 24° N. lat., being locally common in some of the forests of the Shweli river drainage: in the Chindwin valley it extends somewhat farther north, though its northernmost limit has not yet been accurately determined. It extends southward into Tenasserim, eastward into the Shan States, and westward into Arakan. It is probably most abundant, as well as most accessible, in the extensive forests of the Pegu Yoma, the low range of hills running up the centre of Burma and forming the watershed between the Irrawaddy and Sittang rivers. It is found in parts of the dry zone of Upper Burma, but here it does not attain large dimensions. In Arakan it occurs in many localities, often in belts or patches of varying extent. The quality is best in the Sando-way district, where the percentage of pyinkado in the crop is usually higher than it is in most parts of Burma; on the islands, and in the eastern part of the Akyab district, the trees are often stunted and badly shaped.

Pyinkado is found both on hilly and on flat ground, but particularly on the former, attaining its best development on the lower slopes of hills and in well-drained valleys. It thrives best on deep moist porous loam and requires good drainage, for which reason its occurrence on flat ground is decidedly local, being confined to well-drained areas, preferably with a slightly undulating

surface; it avoids low-lying flat ground subject to inundation. The tree is found on a variety of geological formations. On the sandstones and shales of the Pegu Yoma, producing a deep sometimes sandy loam, it thrives extremely well. In the Chindwin valley it is found, often of large size, on sandstone and conglomerate with occasional shale, clay, or limestone. In the Ruby Mines district it occurs to some extent on limestone, sandstone, slate, and shale. Mr. G. R. Jeffery¹ attributes its local occurrence in this district to the fact that it avoids saline and ferruginous soils: thus, although it is present and abundant in the Hintha and Ôndôk blocks, it is wholly absent from the neighbouring Kyauktaung block, where the soil is largely saline and ferruginous. In the Madaya drainage of the Mandalay district it occurs on gneiss and occasional limestone, while east of the Sittang river it is found on gneiss and granitic schist. In the Thaungyin valley of Tenasserim it occurs on argillaceous sandstones and shales, on igneous or metamorphic rocks and on limestone. In various localities it grows on recent alluvium, provided the drainage is good. In the dry zone of Upper Burma it is found to a very limited extent and of small size on sandstone with alternating thin bands of shale. Throughout its distribution it occurs locally and in stunted form on laterite in the dry dipterocarp forest known as *indaing*.

In the natural habitat of the tree the absolute maximum shade temperature varies from 100° to 113° F., and the absolute minimum from 40° to 55° F. As regards rainfall requirements, it is actually found in limited quantity in the dry zone of Upper Burma in places where the normal rainfall is as low as 30 in., though here it reaches only a small size. It may be said in general that where the rainfall is less than 45 in. it does not attain large dimensions, while it grows best with a rainfall of 60 in. and over; actually it is known to grow extremely well with a rainfall of 120 in., and no doubt it thrives in even wetter localities.

The tree occurs in five broad types of forest: (1) upper mixed deciduous forest; (2) lower mixed deciduous forest; (3) evergreen forest; (4) *indaing* forest; and (5) scrub forest of the dry zone.

1. Upper mixed deciduous forest. This is by far the most important type, and the one in which the trees are found in the greatest abundance and attain the largest dimensions. This type is characteristic of hilly country, the hills being often little more than comparatively low spurs, as on the outer fringes of the Pegu Yoma (see Fig. 155): it is the type which comprises the great bulk of the more important teak forests of Burma, and is in the great majority of cases characterized by the presence of bamboos. There are many sub-types of this type; these can be classified to a large extent according to the moistness or dryness of the forest, the bamboos being the best indicators. The moistest sub-type is that which verges on evergreen, and often contains little or no teak; in this sub-type, which is well developed in the moister regions of the Pegu Yoma, pyinkado is sometimes so abundant as to become practically gregarious. This sub-type merges into the typical moist mixed deciduous sub-type and thence through various stages into the driest sub-type of mixed deciduous forest. The typical bamboo of the driest sub-type is

¹ Working Plan for the Hintha, Ôndôk, and Kyauktaung Reserves, Ruby Mines Division, 1908.

Dendrocalamus strictus, while *Bambusa Tulda* is also found in dry forest, though it extends also into the moister sub-types. Other typical bamboos of the upper mixed deciduous forests are *Bambusa polymorpha*, *Cephalostachyum pergracile*, *Oxytenanthera albociliata*, *Dendrocalamus longispathus* (moist valleys in the Pegu Yoma), and *Thyrsostachys Oliveri* (Upper Burma). The pyinkado probably reaches its finest development in upper mixed forest of the moister sub-type, in which *Bambusa polymorpha* grows in greatest luxuriance. In the Pegu Yoma some of its more important associates in the upper mixed type are *Tectona grandis*, *Lagerstroemia Flos-Reginae*, *L. tomentosa*, *L. villosa*, *Homalium tomentosum*, *Terminalia tomentosa*, *T. Chebula*, *T. pyrifolia*, *Sterculia* spp., *Adina cordifolia*, *A. sessilifolia*, *Stephegyne diversifolia*, *Bombax insigne*, *Spondias mangifera*, *Odina Wodier*, *Dalbergia cultrata*, *D. ovata*, *Pterocarpus macrocarpus* (in dry forest), *Cassia Fistula*, *Albizia odoratissima*, *Acacia Catechu* (in drier types), *Schleichera trijuga*, *Berrya Ammonilla*, *Eugenia Jambolana*, *Gmelina arborea*, *Vitex pubescens*, *V. glabrata*, *Premna tomentosa*, and *Anogeissus acuminata*. In moist types verging on evergreen forest *Dipterocarpus alatus* makes its appearance, while in the drier types approaching *indaing* in character the most important trees are *Pentacme suavis* and *Shorea obtusa*. There is a further variety of dry forest without bamboos, exemplified in parts of the Pegu Yoma, locally known as *thitkyin* forest, which is characterized by an extremely plentiful advance growth of pyinkado, and in which the most characteristic species, apart from *Xylia*, are *Tectona grandis*, *Terminalia tomentosa*, *Homalium tomentosum*, and *Lagerstroemia Flos-Reginae*.

In the Chindwin drainage most of the above-mentioned species are also found. In the southern part of this drainage *Acacia Catechu* and *Pterocarpus macrocarpus* are fairly common. The chief bamboos are *Cephalostachyum pergracile*, *Dendrocalamus strictus*, *Bambusa Tulda*, and *Dendrocalamus Brandisii*. *Bambusa polymorpha* is very rare and local.

In the Ruby Mines district pyinkado, though somewhat local, is plentiful in some localities. It is found in three main types of forest: (i) on fertile sometimes rather dry slopes with *Tectona grandis*, *Terminalia tomentosa*, *T. Chebula*, *Vitex pubescens*, *V. alata*, *Pterocarpus macrocarpus*, *Anogeissus acuminata*, *Adina cordifolia*, *Pentacme suavis*, *Odina Wodier*, *Sterculia versicolor*, *S. villosa*, &c., the chief bamboos being *Dendrocalamus strictus*, *Thyrsostachys Oliveri*, and *Cephalostachyum pergracile*; (ii) on flats in bends of streams with *Tectona grandis*, *Lagerstroemia Flos-Reginae*, *Tetrameles nudiflora*, *Adina cordifolia*, *Anogeissus acuminata*, *Terminalia tomentosa*, and *Pterocarpus macrocarpus*, the chief bamboos being *Bambusa Tulda* and *Oxytenanthera albociliata*, and there is often a dense undergrowth of thorny climbers; (iii) in poor open bamboo forest, chiefly of *Dendrocalamus strictus*, and occasionally *Thyrsostachys Oliveri* and *Cephalostachyum pergracile*, on dry shallow soil, where the trees attain small dimensions; here the principal associate species are *Terminalia tomentosa*, *T. Oliveri* (in drier parts), *Pterocarpus macrocarpus*, *Diospyros burmanica*, *Acacia Catechu*, *Adina cordifolia*, *Odina Wodier*, and others, and there is often a dense thorny undergrowth of such shrubs as *Harrisonia Bennetti* and *Cratoxylon prunifolium*.

In the Madaya drainage of the Mandalay district pyinkado is associated with numerous deciduous species, such as *Tectona grandis*, *Pterocarpus macro-*

carpus, *Terminalia tomentosa*, *Gmelina arborea*, &c., with *Pentacme suavis* and *Shorea obtusa* in the drier parts; the chief bamboo is *Thyrsostachys Oliveri*, with *Dendrocalamus strictus* on dry areas.

In the Thaungyin drainage of Tenasserim the most important pyinkado tracts are the semi-moist and dry mixed teak-bearing forests, which are found partly on hill slopes and ridges and partly on flat alluvial ground with sandy soil along the Thaungyin river; in the former areas *Dendrocalamus strictus* is the prevailing bamboo. Pyinkado of large size is plentiful in all the semi-moist forests, especially along the Thaungyin river, its chief associates being *Tectona grandis*, *Terminalia tomentosa*, *Lagerstroemia Flos-Reginae*, *L. tomentosa*, *Adina cordifolia*, *Gmelina arborea*, *Pterocarpus macrocarpus*, *Homalium tomentosum*, and *Odina Wodier*; the principal bamboos, besides *Dendrocalamus strictus*, are *Oxytenanthera albociliata*, *Dendrocalamus Brandisii*, *Cephalostachyum pergracile*, *Bambusa Tulda*, and *B. arundinacea*. Pyinkado is also found to a limited extent in moist forest containing no teak, which occurs chiefly on the higher moist slopes on the east of the Meplè-Thaungyin watershed; this forest is characterized by a dense undergrowth of bamboo, chiefly *Oxytenanthera albociliata*.

2. Lower mixed deciduous forest. So far as pyinkado is concerned this type is of less importance than the upper mixed forest. It occurs on the flat usually alluvial ground of the plains, and merges to some extent into the upper mixed type or into evergreen forest or, where laterite occurs, into *indaing* forest. Pyinkado is not found on the low-lying portions of the alluvial plains, where the forest merges into savannah types, but occurs only where the drainage is good. Its chief companions are *Tectona grandis*, *Lagerstroemia Flos-Reginae*, *L. macrocarpa*, *L. tomentosa*, *Terminalia tomentosa*, *T. belerica*, *T. Chebula*, *T. pyrifolia*, *Homalium tomentosum*, *Adina cordifolia*, *A. sessilifolia*, *Stephegyne parvifolia*, *S. diversifolia*, *Careya arborea*, *Odina Wodier*, *Bridelia retusa*, *Eugenia Jambolana*, *Berrya Ammonilla*, *Eriolaena Candollei*, *Schleichera trijuga*, *Dalbergia cultrata*, *Anogeissus acuminata*, *Diospyros ehretoides*, *Vitex glabrata*, and *Dillenia pentagyna*. Bamboos are usually absent, though in some localities *Bambusa Tulda* occurs along watercourses.

3. Evergreen forest. Although tropical evergreen forest is very frequently found without pyinkado, the tree nevertheless occurs in this type, in common with other large deciduous trees such as *Tetrameles nudiflora*, *Sterculia alata*, *Artocarpus Chaplasha*, and *A. Lakoocha*, as well as lofty evergreen species such as *Dipterocarpus alatus*, *Hopea odorata*, *Anisoptera glabra*, and others, all these forming an upper story over a dense growth of evergreens of many species, with palms and canes. It is probable that this type represents in many cases a progressive succession from deciduous to evergreen forest, and this is borne out by the fact that pyinkado-bearing types intermediate between the deciduous and the tropical evergreen forest are met with, and that in the latter the pyinkado may be represented only by large trees which have survived from the former moist deciduous forest. Mr. A. E. Ross¹ notes an interesting fact regarding the encroachment of evergreen forest and its effect on teak and pyinkado in the forest of the lower Thaungyin drainage in Tenasserim. It was noted that on the edges of evergreen forest within the

¹ Working Plan for the Lower Thaungyin Working Circle, 1909.

fire-protected area the evergreen species appeared to be spreading. Several pyinkado, teak, and other moist forest species were found standing dead in the evergreen near its edge. Many of these trees still had their bark on and had evidently been choked for want of light. Farther in, dry stag-headed trees and fallen trees of these species were occasionally met with.

4. *Indaing* forest. This type of dry dipterocarp forest occurs on laterite or gravel, among its most characteristic species being *Dipterocarpus tuberculatus*, *Pentacme suavis*, *Shorea obtusa*, *Melanorrhoea usitata*, *Buchanania latifolia*, *Dillenia pulcherrima*, and *Diospyros burmanica*. Pyinkado is sometimes fairly plentiful in this type, but the trees are always stunted, and this forest cannot be regarded as an important pyinkado-bearing type.

5. Scrub forest of the dry zone. Pyinkado is not a typical tree of the dry zone of Burma, but is met with to a very limited extent in the better types of dry zone scrub forests on sandstone with alternating thin bands of shale, though it attains only small dimensions; its chief companions are *Pentacme suavis*, *Shorea obtusa*, *Terminalia tomentosa*, *T. Oliveri*, *Tectona Hamiltoniana*, *Acacia Catechu*, *A. leucophloea*, *Cassia renigera*, *Buchanania latifolia*, *Odina Wodier*, *Diospyros burmanica*, and *Schleichera trijuga*.

Some figures may now be quoted showing the prevalence of pyinkado in different forest tracts. The proportion of this species in the lower mixed forests is comparatively small, the highest percentage recorded being 9.4 for the Kangyi reserve of the Zigôn forest division. Some of the plains forests, however, owing to their accessibility, have been heavily worked in the past, and figures regarding these forests may be misleading: thus the Satpôk reserve in Tharrawaddy, with only 3 per cent. of pyinkado, contains numerous stumps of that species. The case of the upper mixed forests is different, for working plan enumerations have been carried out over extensive areas where pyinkado had not previously been worked, and the figures obtained indicate that in many cases, particularly in the moister types of mixed forest, pyinkado is more numerous than any other species, often approaching gregariousness. The following instances may be quoted of sample plots specially rich in pyinkado:

Forest division.	Forest.	Area of sample plot. acres.	Average number of pyinkado trees 3 ft. and over in girth per acre.
Pyinmana	Yeni	133.4	11.4
Nyaunglebin	Aingdon Kun	118.0	10.7
	"	89.0	11.5
	"	100.0	11.1
	West Kun	124.0	14.3
	Yenwe	104.0	10.9
Toungoo	Gwethe	68.8	11.0
Tharrawaddy	Kônbin	41.0	11.5 ¹

¹ Trees 1 ft. in diameter and over.

Outside the Pegu Yoma the richest pyinkado tract hitherto examined is the Nwa working circle of the Myittha forest division in the Chindwin drainage, where enumerations showed an average for the whole tract of 490 pyinkado trees 3 ft. and over in girth per 100 acres, this species forming no less than 24 per cent. of the total growing stock.



FIG. 154 *Alytia dolabriformis*—SEEDLING $\times \frac{1}{8}$
 Seed b e Germination stages f j—Development of seedling to end of first season

The figures furnished by working plan enumerations in the Pegu Yoma are given in the statement on the next page. The figures no doubt contain many discrepancies owing to the inclusion in certain cases of Karen areas, teak plantations, or types of forest in which pyinkado is scarce or absent, but even allowing for these discrepancies the figures are interesting. The statement shows the various forest blocks on either side of the watershed placed opposite each other in their correct geographical positions. In this large unbroken tract of forest running north and south, measuring about 220 miles in length and averaging about 25 miles in width, the forest is of a dry type in the north, becoming moister towards the south; again, the forest on the western side is drier than that in the same latitude on the eastern side. The statement clearly shows in a general way the increase in the quantity of pyinkado on proceeding from the drier to the moister types, whether from north to south or from west to east.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The leaves fall about February and the new leaves appear about April–May. The globose heads of small yellowish flowers appear in March–April, and the pods ripen next December–January, dehiscing on the tree, the hard woody valves bursting open elastically and curving back; the pods fall at the time of or not long after dehiscence, and have usually all fallen by May. The pods are 4 to 6 in. long by 2–2.5 in. broad, brown, flat, woody, falcate-oblong, containing six to ten seeds. The seeds (Fig. 154, *a*) are flat, ovate, oblong, or nearly orbicular, 0.4–0.7 in. by 0.35–0.5 in., brown, smooth, shining, with a moderately hard testa. The percentage of fertility is high, and germination takes place readily; the seeds retain their vitality well for at least a year if kept dry. Occasional bad seed-years occur, but good seed-years are frequent enough to secure ample regeneration where other conditions are favourable.

GERMINATION (Fig. 154, *b–e*). Epigeous. The radicle emerges and descends rapidly; the hypocotyl arches at first and elongates, soon straightening and raising the cotyledons above ground. The testa is either left in the ground or carried up over the cotyledons, dropping with their expansion.

THE SEEDLING (Fig. 154).

Roots: primary root long, moderately thick, terete, tapering, wiry, white or pale yellow at first, turning brown, glabrous or minutely pubescent when young; lateral roots fairly numerous, at first short, afterwards long, fibrous, distributed down main root. **Hypocotyl** distinct from the root, 1–2.3 in. long, terete, tapering slightly upwards or fusiform, white turning green, minutely pubescent. **Cotyledons:** petiole 0.1 in. long or less; lamina 0.7–0.9 in. by 0.5–0.7 in., broadly elliptical or obovate, apex rounded, base sagittate, entire, fleshy, glabrous, upper surface flat or slightly concave, lower surface convex, veins not distinct. **Stem** erect, woody, green turning brown, young parts pubescent; internodes 0.3–1.2 in. long. **Leaves** compound, first pair opposite, usually with one pair, rarely two pairs of leaflets, sometimes trifoliate, subsequent leaves alternate with 1, 2, or 3 pairs of leaflets; bi-compound leaves ordinarily commence to form in the second season. Stipules up to 0.2 in. long, linear lanceolate, acuminate. Rachis (first season) 0.6–5 in. long, pubescent, terminating in a fine bristle. Leaflets opposite, with petiolules up to 0.1 in. long, 0.7–5 in. by 0.25–2 in., ovate, acuminate, entire, glabrescent above, pubescent beneath, terminal pair larger than remaining leaflets, young leaves often copper-coloured.

Prevalence of *Xylia dolabriformis* in the Pegu Yoma forests proceeding from north to south.

Western side of watershed.					Eastern side of watershed.				
No. per 100 acres.	Percent- age of total growing stock.	Forest or working circle.	Approximate rainfall. in.	For- est division.	For- est division.	Approximate rainfall. in.	Forest or working circle.	Percent- age of total growing stock.	No. per 100 acres.
						40	Sinthè	9.5	205
						45	Taungnyo	12.7	190
						50	Pozaungdaung	12.2	275
						55	Ngalaik	16.6	294
						..	Yanaungmyin		
						60	Kaing	14.9	220
						..	Palwe		
						65	Yénbin	21.5	394
						70	Minbyin	15.5	330
						..	Yem	14.1	360
						75	Sang Yane	17.1	317
						80	Kyaukmasin	16.7	317
						..	W. Swa		
						..	Sabyin	23.6	342
						85	Lonyan		
						..	Kabaung	23.3	328
						..	Bondaung	22.0	434
						90-100	Pyuchaung and Pyukun	21.9	385
228	13	{ Satsuwa Tindaw E. Yoma	.. 45 ..	Thayetmyo		75	Sang Yane	17.1	317
280	17.9	N. Nawin	..			80	Kyaukmasin	16.7	317
324	18.6	Middle Nawin	50			..	W. Swa		
248	17.3	S. Nawin	..			..	Sabyin	23.6	342
300	17.5	Chaungzauk	..			..	Lonyan		
(158 ¹)	9.1 ¹)	Shwele	..			90-100	Kabaung	23.3	328
							Bondaung	22.0	434
284 ²	18.2	Taungnyo	55				Pyuchaung and Pyukun	21.9	385
308 ²		Baw bin	60						
190 ²		Gamón	65						
220 ²		Minhla	70						
270 ²		Mokka	..						
211 ²		Kadunbilin	75						
250 ²		Kónbilin	80						
219 ²		Thonze	..						
248	15.6	Rangoon hills	95						

¹ These figures do not afford a fair comparison, as they are calculated on a total containing a considerable area of unproductive forest.

² The working plans give numbers of trees 1 ft. in diameter and over; the number 3 ft. in girth and over would be slightly greater.



FIG. 155 *Xylocopa dolabriformis* (with man at base) in upper mixed forest, Burma: large wound at base of tree caused by fire. Straight smooth-stemmed tree on left is *Homalium tomentosum*



FIG. 156. *Xylocarpus dolabriformis* seedling towards end of second season regularly weeded and watered, height 6 ft. 3 in.



FIG. 157. *Xylocarpus dolabriformis* seedlings 15 months old, showing effect of weeding, Dehra Dun plot to right of staff sown at same time but left unweeded. Staff shows feet.

The growth of the seedling during the first season is only moderate, a height of 5-12 in. being ordinarily attained. In the second and subsequent years, however, the development under favourable conditions is rapid, as the measurements in the statement below will show. Growth is greatly stimulated by regular weeding and loosening of the soil, as well as by moderate watering : it is much impeded by weeds and by stiff soil, as the seedling requires good drainage and soil-aeration.

Fig. 156 shows a plant towards the end of the second season, vigorous growth having been stimulated by regular weeding and watering.

A long taproot is developed at an early age ; it may reach a length of 1 ft. in two months from germination and a length of 1.5 ft. or more by the end of the first season. In the middle of the second season a plant was dug up with a taproot 3 ft. 2 in. long and 0.6 in. in diameter. The seedling stands comparatively heavy shade in its early stages. It is sensitive to drought as well as to frost.

The table below gives a summary of measurements in experimental plots at Dehra Dun, in which the beneficial effects of weeding are clearly demonstrated. The rate of growth for a locality far outside the natural habitat of the species is remarkable.

Xylia dolabriformis : rate of growth of young plants, Dehra Dun.

Condition under which grown.	Height at end of season.			
	1st season.	2nd season.	3rd season.	4th season.
1) In nursery, weeded and watered	0 ft. 3 in.-0 ft. 6 in.	..	..	..
2) In nursery, weeded and watered	0 ft. 4 in.-0 ft. 11 in.	Maximum 3 ft. 9 in.	..	..
3) In nursery, weeded and watered	Maximum 0 ft. 11 in.	6 ft. 3 in. (one plant)	11 ft. 4 in. (girth 6 in.)	17 ft. 4 in. (girth 10 in.)
4) Broadcast sowing (seed lightly covered), irrigated, weeded	Maximum 0 ft. 7 in.	0 ft. 8½ in.-4 ft. 0 in.	..	..
5) Broadcast sowing (seed lightly covered), irrigated, not weeded	Maximum 0 ft. 6 in.	0 ft. 4 in.-1 ft. 5 in. (impeded by weeds)	..	..
6) Broadcast sowing (seed lightly covered), unirrigated, weeded	Maximum 0 ft. 9 in.	0 ft. 9 in.-5 ft. 1 in.		12 ft. 6 in. (girth 6 in. at 4 ft. from ground)
7) Broadcast sowing (seed lightly covered), unirrigated, not weeded	Maximum 0 ft. 6 in.	0 ft. 3 in.-0 ft. 11 in. (impeded by weeds)		
8) Natural conditions (seed scattered on surface of ground), not weeded after sowing—in open	Maximum 0 ft. 5 in.	All killed by drought		
9) Natural conditions (seed scattered on surface of ground), not weeded after sowing—in open	0 ft. 2 in.-0 ft. 5 in. (impeded by weeds)			
10) Natural conditions (seed scattered on surface of ground), not weeded after sowing—in slight shade	0 ft. 3 in.-0 ft. 5 in.			
11) Natural conditions (seed scattered on surface of ground), not weeded after sowing—in heavy shade	0 ft. 3 in.-0 ft. 7 in.			

Fig. 157 shows in a striking manner the effect of regular weeding. A plot was sown broadcast : no watering was done, but the portion to the left of the staff was regularly weeded, the soil being kept loose, while the portion to the right of it was left unweeded. The effect of the weeding after fifteen months is very marked.

SILVICULTURAL CHARACTERS. The tree is a shade-bearer, particularly in youth, although in this respect it cannot compete with the more shade-bearing evergreens. It is sensitive to drought in youth. For its best development it requires a moist, deep, well-drained soil ; it is sometimes found on dry shallow soils, where, however, it never reaches large dimensions. Owing to its thin bark it is readily injured by fire, large wounds due to this cause being frequently found at the base of the tree, as shown in Fig. 155. The tree is attacked by a parasitic fungus, *Fomes fulvus*, Fries, the spores of which probably gain admission through wounds (see *Indian Forester*, xxvi. 19 and 160). The tree coppices well up to a moderate size : it is not known if it produces root-suckers like the Indian species.

NATURAL REPRODUCTION. Experiments at Dehra Dun gave the following results : (1) Germination takes place very readily at the commencement of the rainy season. (2) Bare ground favours germination, but if the ground is hard the germinating seedling is liable to dry up before the radicle penetrates the soil ; loosening the soil greatly helps matters. (3) Mortality also takes place during germination owing to (a) the rotting of the radicle or the seed in heavy wet weed-growth or on badly-drained ground, (b) the destruction of the radicle by birds and insects, (c) the drying up of the radicle or the swollen seed if exposed to the sun after germination has started ; this is a very fruitful cause of death. (4) Under shade (other than that of heavy wet weed-growth) germination takes place readily, and the seedling can establish itself without difficulty ; in shady places the radicle may creep along the ground for some distance before it gains admission to the soil, and even roots and leaves may form before the seedling gains a footing, which would be impossible in the sun.

These results appear to indicate that natural reproduction is favoured by loose bare ground under shade where the drainage is good. The question of light necessary for its establishment is considered below.

In the forest young pyinkado seedlings are often found in large quantities under these conditions. On the surface of a new road under construction through the Kōnbilin forest in Tharrawaddy, where the soil had recently been dug up and levelled, in June 1904 I observed seedlings in countless numbers ; these were so numerous that it was impossible to walk without treading on them at every step. In the same forest pyinkado seedlings have frequently been observed in quantity under the shade of teak plantations of different ages.

The effect of fire-protection on the natural reproduction of pyinkado is often most pronounced, and annual reports frequently contain references to the quantity of seedlings appearing in fire-protected forests. It is an undoubted fact that in the moister types of deciduous teak-bearing forest in the Pegu Yoma teak is to a large extent being replaced by pyinkado under the influence of fire-protection, which, while greatly assisting the reproduction of pyinkado, has a correspondingly adverse effect on that of teak. The stimulus given by fire-protection to pyinkado reproduction has been observed in moist and dry upper mixed forest, both with and without bamboos, as well as in lower mixed forest. On the other hand, cases of good reproduction in areas annually burnt may also be observed, though such cases occur only where the state of the soil-covering is such as to preclude severe fires. The effect of

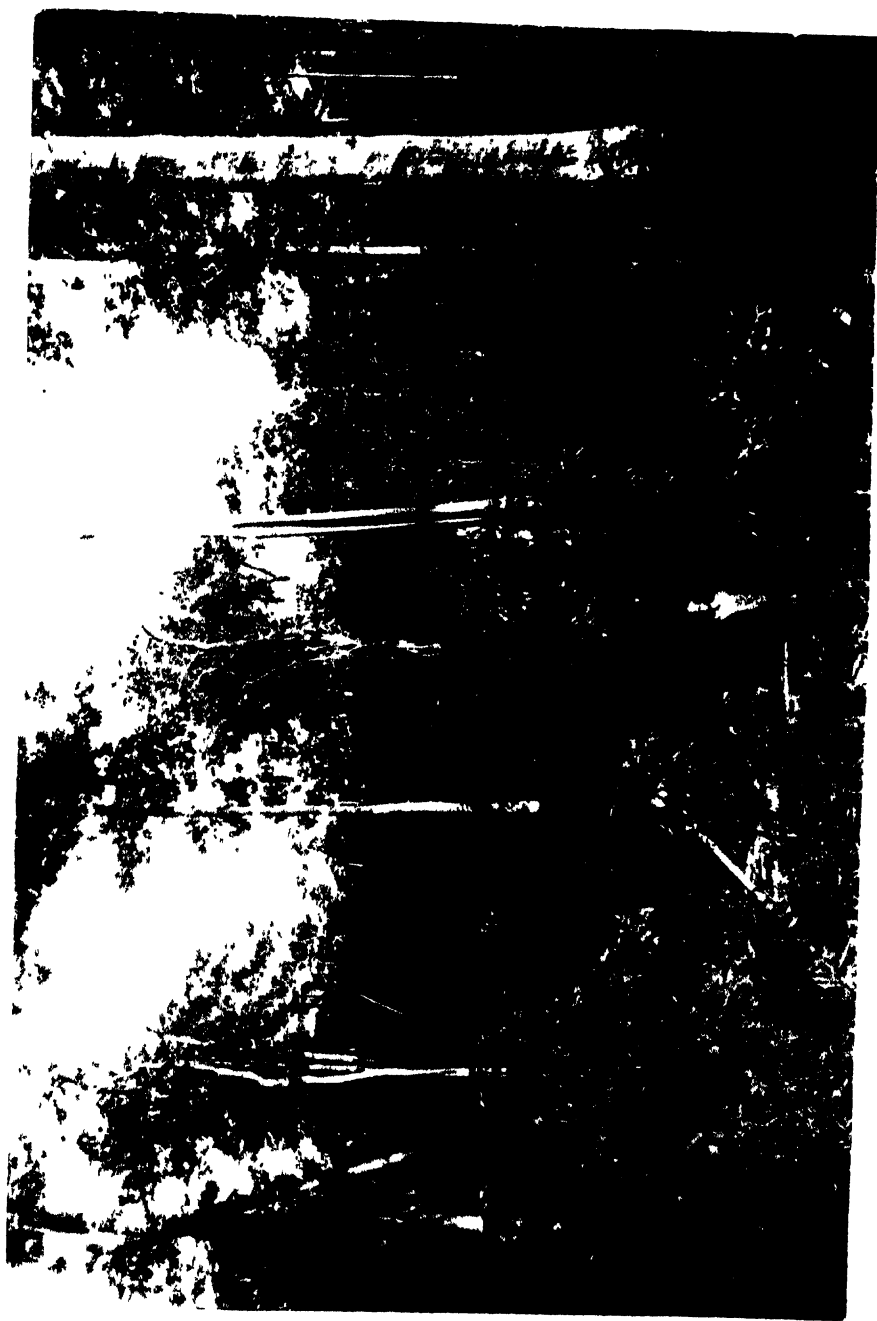


FIG. 158 *Xylia dolabriformis*, dense natural reproduction in fire-protected forest, establishment assisted by gradual opening of the overhead canopy combined with repeated cleanings, overwood consisting of teak and other trees ready for removal. Minhla reserve, Tharrawaddy, Burma



FIG. 159. *Xylia dolabriformis*, dense natural sapling crop in fire-protected forest, assisted by gradual opening

fire-protection, however, does not appear to be universally beneficial, for cases are recorded, particularly from South Tenasserim, where owing to the thick carpet of leaves, and possibly owing sometimes to the dense undergrowth, the seedlings fail to establish themselves in fire-protected forest. This appears to indicate that, as in the case of teak, when the type of forest passes a certain degree of moisture protection induces conditions adverse to successful reproduction; this degree is passed at a considerably drier stage in the case of teak than in the case of pyinkado.

Another factor of great importance to the establishment of pyinkado reproduction is light. Although seedlings appear under fairly heavy shade and may even persist for a time, they become suppressed and killed out unless a moderate amount of light is admitted. Operations carried out in Tharrawaddy to assist natural reproduction have shown, however, that if the overhead cover is opened out severely a heavy growth of grass and weeds tends to spring up in which pyinkado seedlings, though they may appear in large numbers, become suppressed, while, on the other hand, if the cover is removed gradually weeds are prevented from coming in to the same extent and the advance growth of pyinkado grows rapidly: repeated weeding and cleaning in the earlier years is necessary, however, in order to bring up the young crop. Figs. 158 and 159 illustrate the manner in which natural young crops of pyinkado can be established in fire-protected forest by the gradual opening of the canopy combined with weedings and cleanings. Observations have been recorded in various localities regarding the quantity of reproduction which springs up in areas where felling and bamboo cutting have taken place, the disturbance of the soil no doubt assisting as well as the admission of light.

Mr. T. W. Forster,¹ writing of the effect of the admission of light on the reproduction of pyinkado in Tharrawaddy, notes that whereas young pyinkado is well distributed over areas where bamboos are absent, it is conspicuous by its absence in many bamboo areas except along the outer edges where side light has penetrated and in places where clumps have died after seeding. That seedlings do appear in large quantities in untreated bamboo areas may be realized from the following countings made in two plots: (1) area $\frac{1}{4}$ acre: seedlings present, 3,309, or 13,200 per acre; (2) area 1 square chain: seedlings present, 1,088, or 10,800 per acre. In such cases, however, if sufficient light is not admitted a very large proportion of these die off. The following countings on a linear survey 9 chains in length covering 1.8 acres in untreated bamboo forest in the Mókka reserve show the extent to which the establishment of seedlings and saplings is prevented by the effect of overhead cover:

Seedlings 1 ft. in height and over	3,691
Poles 8 in.-1 ft. in girth	21
Trees 4-5 ft. in girth	2
Trees 5-6 ft. in girth	2
Trees over 6 ft. in girth	2

Within recent years special attention has been paid in some of the Pegu Yoma tracts to the question of obtaining natural reproduction of pyinkado. It has been demonstrated clearly that once their roots have become well established young pyinkado plants are capable of surviving severe burning almost as well as teak, and although burnt back they afterwards send up strong

¹ Ind. Forester, xxxviii (1912), p. 455.

vigorous shoots. This takes place even after severe fires in flowered bamboo areas. Experiments in Prome, Tharrawaddy, and Toungoo have shown that natural reproduction can be secured in quantity by cutting bamboos and other growth in the vicinity of seed-bearers, in order to lighten the cover, and thoroughly burning the cut material. Natural pyinkado seedlings appear in quantity on the burnt ground; thereafter the area is fire-protected and the young crop is regularly weeded, while light is admitted gradually by the removal of the overwood. This results in the establishment of dense young crops of pyinkado.

The immunity of well-established pyinkado seedlings from destruction by fire indicates the treatment which would probably be successful in mixed teak and pyinkado crops. This would consist of encouraging pyinkado advance growth by a slight opening of the canopy near seed-bearers, accompanied by burning; for some years the area would be fire-protected and the young pyinkado would be weeded if necessary until well established. A clear felling and burning of the area would then secure teak reproduction, while the young pyinkado, after being burnt back, would shoot up again from the base. Further weeding of the young mixed crop would then be necessary until it is established. It may be noted in this connexion that pyinkado reproduction often appears in teak *taungya* plantations in the form not only of seedlings but also of coppice-shoots from the bases of saplings which have been burnt back.

Natural reproduction of pyinkado is sometimes found in great quantity in the rather dry type of forest known as *thitkyin* alluded to above, containing few or no bamboos; this reproduction is the result of fire-protection, but the young plants are kept in suppression, and few succeed in making their way up unless the canopy is opened.

ARTIFICIAL REPRODUCTION. Experiments at Dehra Dun have shown that direct sowing gives much greater success than transplanting from the nursery. Transplanting, if carried out carefully in rainy weather, was found to be successful with small plants in the first rainy season, but not with large plants in subsequent years. Pruning down the stem and the root did not prove successful, either in the first year or subsequently.

The beneficial effects of thorough weeding and loosening of the soil have already been alluded to under 'the seedling', and hence line sowings, where these can be carried out most effectively, are indicated as likely to give the best results.

In the Kyangin reserve of the Henzada forest division a mixture of teak and pyinkado has been tried with field crops in shifting cultivation (*taungya*) on a fairly extensive scale, but owing to the different requirements of the two species as regards germination the success has not been great. Teak seed, in order to germinate successfully, requires to be put in early in order to obtain the benefit of the alternating showers and hot sun at the commencement of the rainy season. Pyinkado seed, on the other hand, germinates with the first shower, and in an open *taungya* the germinating seedling is dried up on the next sunny day. To sow the pyinkado later when the rains have well set in would add to the cost of the plantation, and might be difficult in practice. A small *taungya* plantation of pure pyinkado was formed in the Tharrawaddy division about 1900. This I saw in 1904, and the plants were few in number

and in poor condition : the surrounding forest contained pyinkado trees of good quality, and the poor condition of the plantation, in which the ground was covered with a thick growth of grass, was probably due to this growth of grass, to unfavourable soil conditions induced by the removal of the forest cover, and to the exposure of the plants to the sun. The readiness with which natural reproduction of pyinkado sometimes springs up in teak plantations would indicate that it might be introduced successfully as an under-story in such plantations if the correct degree of light is obtained : sowings of pyinkado in lines between the lines of teak, after the latter have been sufficiently thinned out, should not be difficult to carry out.

2. *Xylia xylocarpa* (Roxb.), Hole in *Ind. For.*, xxxviii. 463. Vern. *Jamba*, *yerul*, *suria*, Mar. ; *Jambe*, *tiruwa*, Kan. ; *Irul*, Tam. ; *Tangedu*, Tel. ; *Irumulla*, *kada*, Mal.

A moderate-sized to large deciduous tree. Leaves bipinnate with one pair of pinnae, each pinna with two to six pairs of leaflets. Bark 0.2-0.5 in. thick, smooth, reddish grey, exfoliating in large irregular plates. Wood very hard, reddish brown, durable, liable to split in seasoning, used for house and bridge construction.

The tree is considerably smaller than the Burmese species, seldom reaching a height of more than 60 ft. and a girth of more than 6 ft. ; in dry localities and on poor ground it attains much smaller dimensions than these, and produces a somewhat crooked and fluted bole.

DISTRIBUTION AND HABITAT. This tree occurs in the Indian Peninsula, extending as far north as Bombay in the west, Orissa in the east, and the Balaghat district of the Central Provinces in the centre. It extends southward to Travancore, but is absent from the south of that state. It is not found in the dry districts of the Deccan. It is plentiful throughout the deciduous forests of the Western Ghats, in the Belgaum and North Kanara districts of Bombay, and in South Canara, Malabar, and thence south to Travancore. Here its most important companions are teak, *Terminalia tomentosa*, *T. paniculata*, *Lagerstroemia lanceolata*, *Dalbergia latifolia*, *Pterocarpus Marsupium*, *Adina cordifolia*, and *Schleichera trijuga*. It is, however, a typically gregarious tree, often forming nearly pure crops, especially on abandoned cultivation. In the east of the Peninsula it is plentiful in some of the deciduous forests of the Godavari district, where it also becomes more or less gregarious. It is locally common in Ganjam. In the Puri district of Bihâr and Orissa it occurs on low hilly country, where it is sometimes mixed with sal, forming pole crops. In the Central Provinces it is found locally in mixed deciduous forests on hill slopes and in valleys in Chanda, Bhandara, Balaghat, Raipur, and Nagpur, sometimes forming dense pure young crops under teak and other species.

The tree is found on various geological formations, such as granite, gneiss, mica schist, basalt, trap, quartzite, sandstone, and limestone, while it is sometimes very plentiful on laterite, though on this formation it does not appear to attain large dimensions.

In its natural habitat the absolute maximum shade temperature varies from 95° to 115° F., the absolute minimum from 37° to 62° F., and the normal rainfall from 50 to 180 in. or perhaps more.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The leaves fall about

February and the new leaves appear in March or April, the flowers appearing at the same time. The globose fragrant flower-heads are yellowish white, 0.5–0.7 in. in diameter, with numerous very small flowers. The pods commence ripening next December, and the seed as a rule all falls by March. The pods are brown, 4–6 in. long by 2–2.5 in. broad, flat, woody, falcate-oblong, containing six to ten seeds. The pods dehisce on the tree, the hard woody valves bursting open elastically, curving backwards and ejecting the seeds. The open pods do not remain long on the tree, and have usually all fallen by the end of May; the hard valves may then be found in quantity on the ground. The seeds (Fig. 160, *a*) are flat, ovate, oblong or nearly orbicular, 0.5–0.7 in. by 0.35–0.5 in., brown, smooth, shining, with a moderately hard testa.

GERMINATION (Fig. 160, *b–d*). Epigeous. The testa splits at one end and the radicle emerges and descends rapidly. The hypocotyl arches and elongates, soon straightening and raising the cotyledons above ground. The testa is usually carried up over the cotyledons, falling to the ground with their expansion.

THE SEEDLING (Fig. 160).

Roots: primary root long, moderately thick, terete, tapering, wiry, glabrous or minutely pubescent when young: lateral roots fairly numerous, at first short, afterwards long, fibrous, distributed down main root. **Hypocotyl** distinct from the root, 1.5–2.5 in. long, fusiform or tapering slightly at the lower end, white turning green, minutely pubescent. **Cotyledons**: petiole 0.05 in. long, thick: lamina 0.7–0.9 in. by 0.5–0.6 in., broadly elliptical or obovate, apex rounded, base sagittate, entire, fleshy, glabrous, upper surface flat or slightly concave, lower surface convex, veins not distinct. **Stem** erect, woody, green turning brown, young parts pubescent; internodes 0.3–1.2 in. long. **Leaves** compound, first pair opposite, paripinnate, with two pairs of leaflets, subsequent leaves alternate with 1, 2, or 3 pairs of leaflets, very rarely trifoliate; bi-compound leaves, with leaflets up to six pairs, are ordinarily produced in the second season. Stipules up to 0.2 in. long, linear lanceolate, acuminate, pubescent. Rachis (first season) 0.8–5 in. long, pubescent, terminating in a fine bristle. Leaflets opposite, with petiolules up to 0.1 in. long, 0.7–5 in. by 0.25–2 in., ovate or ovate lanceolate, acuminate, entire, glabrous above, pubescent on the veins beneath, terminal pair larger than remaining leaflets, young leaves often copper-coloured.

Nursery-raised seedlings in Malabar reach a height up to 1 ft. in the first season, and between 2 and 3 ft. by the end of the second season.

The seedling stands a good deal of shade when young, though when once established it benefits by the admission of light. Experience gained in sowings in Coorg shows that it is sensitive to drought. A long taproot is developed early, and may attain a length of 1 ft. or more within a month of germination. As in the case of the Burmese species, the growth of the seedling is greatly stimulated by weeding. The young plants are not eaten by cattle.

SILVICULTURAL CHARACTERS. The tree is a shade-bearer, particularly in youth: it owes its gregariousness in part to this character, which enables it to gain a footing under the moderate shade of mixed deciduous forest, though it cannot compete with the heavy shade-bearers of the evergreen forests. Although it grows best on deep soil overlying sandstone and crystalline rocks it is usually more gregarious on shallow soil on laterite, though here it does

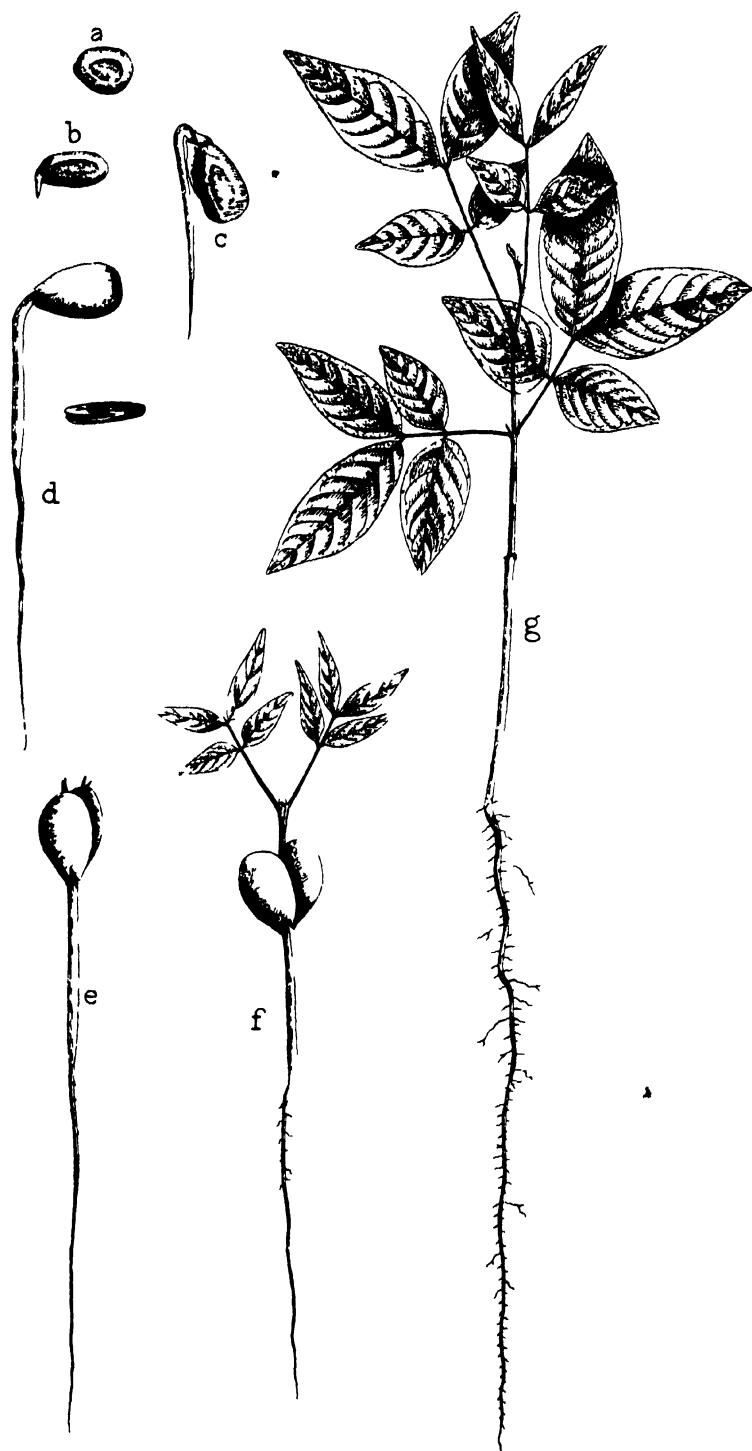


FIG. 160. *Xylia xylocarpa*. Seedling $\times \frac{1}{2}$
a, seed ; *b-d*, germination stages ; *e-g*, development of seedling during first month.

(3) *Coppice*. Measurements in coppice coupes in the Karwar fuel reserves, West Kanara forest division, Bombay, gave the following results from the average curve after plotting :¹

Age in years.	Mean girth at breast height.	
	ft.	in.
5	0	6
10	0	9.5
15	1	0.2
20	1	2.3

Measurements in 1912-13 of coppice-shoots one year old in the Bhandara forest division, Central Provinces, showed an average height of 6 ft. 8 in. for *Xylia* as against 7 ft. 1 in. for teak. Measurements by Mr. H. Gass in 1898-9 in coppice coupes in Kadike block, South Canara district, Madras, gave the following results :²

Xylia xylocarpa : coppice measurements, South Canara.

Age. years.	Girth.		Height.		Number of shoots per stool.
	Mean. in.	Maximum. in.	Mean. ft.	Maximum. ft.	
2	—	—	16	20	1 to 20, average 10
3	6.6	10	15	20	

3. ACACIA, Willd.

This important genus contains over twenty Indian species as well as some introduced species, the three most important of the latter being the Australian trees *A. decurrens*, *A. dealbata*, and *A. Melanoxyton*. The Indian acacias are essentially xerophilous, occupying for the most part the dry and arid regions where the forests are often of the nature of open thorny scrub : some of the species assume the spreading flat umbrella-like crowns characteristic of open xerophilous woodland in the tropics, for example *A. planifrons*, *A. Latronum*, and *A. leucophloea*. The Indian tree species are essentially light-demanding, regenerating on open ground and being intolerant of suppression. Some species reproduce most freely on recent riverain alluvium, notably *Acacia Catechu* and *A. arabica* ; *A. Farnesiana*, an introduced species, also runs wild gregariously in river-beds. Some species have indehiscent or tardily dehiscent pods, e.g. *A. arabica*, *A. modesta*, *A. Senegal* ; others have dehiscent pods, e.g. *A. Catechu*, *A. Latronum*. The seeds of acacias as a rule retain their vitality for a considerable time. Germination is epigeous in all the species examined.

Some species coppice well, for instance *A. Catechu*, *A. modesta*, *A. leucophloea*, *A. dealbata*, *A. decurrens* ; others coppice with less freedom, and in some localities hardly at all, for example *A. arabica* and *A. Melanoxyton*.

Root-suckers are probably produced on occasion by most if not all species ; even *A. arabica*, which does not ordinarily produce suckers, does so occasionally, while *A. Catechu* does so sometimes when the roots are exposed.

¹ Working Plan for the Karwar Fuel Reserves, West Kanara Division, Bombay, D. A. Thomson, 1904.

² Inspection note, 1899.

Suckers are produced more freely by *A. planifrons* and *A. leucophloea*, and in profusion by *A. dealbata* and *A. decurrens*.

Species 1. *A. arabica*, Willd.; 2. *A. leucophloea*, Willd.; 3. *A. Catechu*, Willd.; 4. *A. modesta*, Wall.; 5. *A. Senegal*, Willd.; 6. *A. planifrons*, W. and A.; 7. *A. Latronum*, Willd.; 8. *A. Farnesiana*, Willd.; 9. *A. eburnea*, Willd.; 10. Australian acacias: (1) *A. decurrens*, Willd., (2) *A. dealbata*, Link, (3) *A. Melanoxydon*, R.Br.

1. *Acacia arabica*, Willd. Syn. *Mimosa arabica*, Lam. Babul. Vern. *Babul*, Hind.; *Kikar*, Pb.; *Babar*, Sind; *Jali*, Kan.; *Nella tuma*, Tel.; *Karu velam*, Tam.

A moderate-sized almost evergreen tree with a short trunk, a spreading crown, and feathery foliage. Bark dark brown, nearly black, pinkish brown and hard inside, with regular deep longitudinal fissures which very often run spirally up the tree. Young branches green, pubescent. Stipular spines straight, white, up to 2 in. long, variable, sometimes absent in old trees.

The tree varies much in size, remaining little more than a shrub in some localities, and in others attaining a height of 50 to 60 ft. or even more, and occasionally a girth of 8 to 10 ft. Brandis says the largest girth recorded is 16½ ft. near Multan.

Acacia arabica is probably the most important tree in the drier parts of India. The sapwood is whitish and large: the heartwood is pink, turning reddish brown on exposure, hard and very durable if well seasoned. The wood is used for building, carts and carriages, wheel-work, agricultural implements, boat-building, and many other purposes, and is an excellent fuel. The bark is extensively used for tanning. The pods are rich in tannin, and are also largely used as fodder for cattle, goats, and sheep. The leaves and twigs are used as fodder and the thorny branches as fencing material. The bark exudes a gum largely used in dyeing and calico-printing and for native medicine. Lac is grown on the tree in Sind. In the dry hot regions in which it grows it is a useful shade tree with its spreading evergreen crown, and although its shade is somewhat light it is frequently grown on camping grounds and along roadsides.

VARIETIES. Several varieties of *Acacia arabica* have been distinguished. There are three ordinarily recognized varieties in India, which come true to seed: these are—(1) The typical *A. arabica* with spreading shady crown and moniliform pods. This is the *godi*, *teli*, or *telia babul*, the wood of which is much prized: this variety is the one of most importance economically, and the one extensively grown in plantations or natural forest crops. (2) Var. *vediana*, the *vedi*, *kavadi*, *kaora*, *kaulia*, or *kauria babul*. As compared with the typical or *telia* variety this one is smaller, with a shorter bole, the bark is rougher and more fissured, with more pronounced exfoliation, the pods are flat and little constricted between the seeds and are on shorter stalks, the spines are more numerous, stouter and whiter and up to 2½ in. long, the crown is more spreading, while the branches are more twisted and interlacing. The wood of the *kauria babul* is inferior to that of the *telia*, and is usually considered fit only for firewood, though in cases of necessity it is used as timber, particularly for agricultural implements: hence this variety is cut or weeded out wherever possible in favour of the *telia*. This variety, which is common

in the Deccan, appears to be a xerophytic form of the typical variety. (3) Var. *cupressiformis*, the *ramkanta* or *ramkati babul* or *kabuli kikar*. This variety is recognized by its broom-like (cupressiform) ascending branches: the stem is tall and the branches are thin. It is found in parts of the Punjab, Sind, Rajputana, and the Deccan, where it is fairly common in the Poona district. In Berar there is a religious prejudice against using its timber. The word *ramkati* signifies Rama's *kati* or wand.

The present account of this tree will relate to the *telia* or typical variety unless the contrary is stated, since this is the important variety for forest purposes.

DISTRIBUTION AND HABITAT. *General distribution.* *Acacia arabica* is probably indigenous in Sind, Rajputana, Guzerat, and the northern Deccan; it is cultivated or self-sown throughout most of the drier parts of India, but not in the extreme north-west of the Punjab, where the winter cold is too severe. It is not found in the moister regions. It has been introduced into parts of the dry zone of Upper Burma and has spread to some extent. It is essentially a tree of the plains, occurring on flat or gently undulating ground and ravine country, but not extending into hilly regions. The tree is found also in Africa and Arabia.

Climate. The babul is characteristic of dry regions, but will not thrive without irrigation if the climate is too arid. In regions where it is indigenous or has become naturalized the absolute maximum shade temperature varies from 105° to 122° F., the absolute minimum from 30° to 60° F., and the normal rainfall from 3 to 50 in. In regions of low rainfall such as Sind, however, the existence of the tree is rendered possible only by river inundations: otherwise it is doubtful if the babul is capable of flourishing with a rainfall of less than 20 in., in which connexion Talbot remarks: ¹ 'Quite recently a very large area (over 50,000 acres) of reserved forest in the Poona district, where laborious efforts had been made over a long series of years to raise *babul*, had to be disforested, as it was found that the rainfall was insufficient, even in good soil, to produce anything but small, stunted, and decaying stems of very little climatic or economic value.'

Soil. The two commonest types of soil on which the babul occurs are riverain alluvium subject to inundations and black cotton soil. The former is exemplified on a large scale in Sind and to a lesser extent along the rivers of the Deccan. Black cotton soil is common in many parts of the Peninsula and in the southern part of the Indo-Gangetic plain. It is a stiff soil which absorbs large quantities of water in the rainy season, becoming sodden like a sponge: in the dry season it dries and contracts, forming large deep cracks all over the surface of the ground, and it is only by sending its long taproot down into the moister subsoil beneath that the young plant is able to survive the dry season and establish itself.

Apart from the two classes of soil mentioned, however, the tree is also frequently found on other types of soil, for example over large stretches of country on alluvial loam in the plains of northern India, on loamy soil in the Peninsula, and in tank beds in the Madras Presidency. In any type of soil, however, it is essential that there should be a sufficient degree of permanent

¹ For. Flora Bombay, i. 482.

moisture in the soil and subsoil, for in this respect the babul is exacting. Shallow soils with underlying sheet rock or beds of *kankar* have a stunting effect: on such ground the *kauria* usually replaces the *telia* variety where both occur, and the same applies to saline soils. The capacity of the babul for existing on saline soils appears to depend on the presence of a considerable amount of moisture in the soil. In Sind it cannot exist for any length of time on saline soil, but here this soil denotes a failing water-supply, a condition which is unsuitable for the growth of the tree in the dry climate of Sind. In Berar, according to Mr. Shrinivasulu Nayadu,¹ 'the existence of soda salts to a large extent in the soil favours the growth of babul and its few associates to the exclusion of other trees.' Many of the saline tracts, however, are on the alluvium along the Purna river, where there is a considerable amount of moisture in the soil. That the babul can actually flourish in salt water, and that absence of soil moisture rather than salinity is probably the main reason for its failure to grow on dry saline soils, is indicated from the following quotation from the Madras Forest Report for 1909-10: 'The experiments conducted in Lower Godavari and Kistna for promoting babul growth on the saline soils have not been successful, but inspection showed precisely the defects. In Lower Godavari the area was blank; it was evident that the water ran off almost at once. In Kistna the area was on a slope, the upper part blank, the lower part and hollows filled with babul seedlings, some of which, only one or two years old, were 5 ft. or 6 ft. high. It is evident, then, that if the water can be retained for some time, until the roots reach moisture level, babul will succeed. Nor is fresh water necessary below, for babul was found flourishing with its roots in perfectly salt water creeks.' The same is observable along brackish creeks near Bombay, where the tree is seen in close proximity to mangrove species.

TYPE OF FOREST. *Acacia arabica* is a typically gregarious tree, forming crops which are pure or in which it is usually the most prevalent species. It is a strong light-demander, and the crops come up in even-aged groups or patches of varying extent. Forests of *Acacia arabica* are frequently termed babul *bans* and sometimes babul meadows, the latter term referring to the grassy undergrowth so prevalent in forests of this species. Its companions vary in different localities: these, together with its mode of occurrence, can best be dealt with for different localities separately.

Sind. Sind contains by far the most extensive babul tracts in India, the area of babul forest being roughly estimated at 172,000 acres, though this area is subject to constant change owing to river action. The babul tracts are situated on both banks of the river Indus. The distribution, and indeed the existence, of the babul in Sind is governed by this river and its effect on the soil moisture, for climatically Sind is unsuitable for the growth of babul. In the regions where the tree is found the absolute maximum shade temperature varies from 116° to 122° F., and the absolute minimum from 30° to 40° F., while the normal rainfall varies from 3 to 10 in. Under ordinary circumstances it would be impossible for the babul to exist under rainfall conditions such as these, and it is to the annual inundations of the Indus that the babul forests owe their origin and existence. The influence of the rainfall is of small

¹ Ind. Forester, xxxv (1909), p. 493.

importance compared with that of the floods. The Indus river, which is fed by the Himalayan snows and receives during its course through the Punjab plains the drainage of the four other large snow-fed rivers of that province, annually floods a large stretch of country on either bank. The flood season commences about the beginning of May with the melting of the snows and continues, with occasional interruptions, until July and sometimes later, the river thereafter subsiding until it reaches its winter level about the end of October. The extent and duration of the river floods vary greatly from year to year, and this variation has a marked influence on the conditions affecting forest growth.

The powerful river action causes the formation of new land in the shape of fresh alluvial deposits, and the loss of much existing land through erosion. The new alluvial river deposits (known locally as *kacha* ground) become densely covered in one or two years with a growth of *Tamarix dioica* and *T. Troupii* from water-borne seed, and of *kank* grass (*Saccharum spontaneum*). Where the grass is not too dense, seedlings of *Acacia arabica* soon make their appearance amongst the tamarisk, the seed being dropped by cattle or conveyed by water: the tamarisk undoubtedly assists the babul to establish itself by protecting it from frost. The level of this new ground is gradually raised in course of time by subsequent alluvial deposits along its riverain edge, but as long as the land is subject to annual inundations the babul continues to flourish, other conditions being favourable. If, however, the flood water is shut out or the ground becomes elevated above the reach of ordinary floods the babul commences to languish, and unless there is sufficient subsoil moisture by percolation from the river or from perennial canals the trees die off if the flood water is withheld for three or four years: sufficient percolation from the river, however, is exceptional in ground not subject to floods. It has been estimated that the minimum depth of surface flooding necessary for good babul growth varies from 2 inches on the stiffest to 8 inches on the most porous soils. Deeper flooding is common, and the babul benefits rather than otherwise provided the water drains off at the end of the flood season, for prolonged inundation on low-lying ground is apt to kill off young plants which have been submerged.

Although the most flourishing babul forests are those which are now in riverain situations subject to annual floods, there exist also forests situated some miles from the river, the majority of which formerly received annual flood water. Within the past forty years, however, embankments constructed by the Irrigation Department along both sides of the Indus have shut off the forests from their annual supply of flood water. To a large extent this has resulted in the disappearance of the babul, its place being taken by the deep-rooted and hardier *Prosopis spicigera*. Where the babul has survived it is in a weakly condition, except where it obtains a more or less adventitious supply of water from the surplus drainage from neighbouring cultivation or from occasional breaches in the river embankments. Some of the forests are also irrigated from canals. For some years past steps have been taken to remedy this state of affairs by the construction of sluices in the river embankments, connecting with distributary channels leading into the forests, and by the embankment of forest boundaries to head up water. Whether or not these works will prove

remunerative remains to be seen, but in 1911 the Deputy Conservator of Forests in charge of the Sind circle recorded the following opinion : ' These schemes are bearing beneficial results, but in my opinion their total cost, together with the large annual outlay required to maintain them in efficient order, will be found in the future to be out of all proportion to the revenue likely to be yielded by the forests concerned. These irrigation schemes are complicated in many instances by the necessity on the one hand of protecting adjoining cultivation from forest flood water, on the other hand of not interfering with the customary water supply of cultivation beyond forest limits, and lastly by the difficulty of draining most of the forests so irrigated, at the close of the flood season. When and if a solution of these difficulties can be found, it almost invariably implies greater expense, both capital and recurring. I would therefore recommend that all inland forests should be gradually discarded whenever opportunities occur of acquiring riparian areas instead, so as to maintain undiminished, and to increase if possible, the total area under forest, while at the same time abolishing the difficulties, expense, and interference with more legitimate forest duties entailed by complicated schemes of irrigation.'

The alluvium of which the plains of Sind are formed consists of varying proportions of sand and clay, from pure sand to clayey loam. In places not subject to annual flooding patches of saline soil known as *kallar* often occur : such soil is produced by the evaporation of subsoil moisture containing salts in solution, resulting in the exudation of a whitish efflorescence on the surface of the ground, while the soil itself is usually darker in colour and moister than the normal soil. Babul does not grow on this saline soil where the salinity is at all marked ; it gives way to tamarisk, which in turn yields to *Salvadora*, while finally chenopodiaceous plants such as *Suaeda fruticosa* and *Salsola foetida* mark the last limit of vegetation when the salts become too concentrated for the existence of other species.

Acacia arabica is far more plentiful in lower Sind than in upper Sind. In the latter it is replaced to a great extent by the hardier *Prosopis spicigera*, owing no doubt principally to the greater intensity of the frost, the climate of lower Sind being milder owing to its proximity to the sea ; also the duration and extent of the river inundations is greater in lower than in upper Sind, and this further influences the distribution of the babul.

The most important associates of the babul in Sind are *Tamarix dioica* and *T. Troupii*, which are capable of standing soil conditions both too moist and too dry for the babul, but thrive well along with it ; *Populus euphratica*, which appears on new alluvium along with the babul ; and, to a lesser extent, *Prosopis spicigera*. The last-named species usually appears when the land has become elevated above the reach of all but abnormal floods, and as a rule indicates a failing water-supply ; it is, however, also frequently met with in areas suitable for babul except for a dense growth of grass, the presence of *Prosopis* in place of babul being due to the greater power of resistance to suppression possessed by the former. Occasionally *Tamarix articulata* also appears with *Prosopis*. As the ground becomes drier *Salvadora oleoides*, *S. persica*, and *Capparis aphylla* make their appearance. Among other species, some of them introduced, which are occasionally found in the babul forests

are *Acacia Farnesiana*, *Albizia Lebbek*, *Tamarindus indica*, *Parkinsonia aculeata*, *Zizyphus Jujuba*, *Azadirachta indica*, *Cordia Myxa*, *C. Rothii*, and *Ficus bengalensis*.

Northern and central India. *Acacia arabica* is scattered in greater or less abundance in suitable localities in the plains of the Punjab and United Provinces, and is frequently grown along canal banks: it is occasionally found in the drier parts of Bihar and Chota Nagpur, on embankments, waste lands, &c. In the Punjab it does not extend to the extreme north-west, where the cold in winter is too severe, but elsewhere it is one of the commonest trees of the plains, attaining a good size near water and in irrigated tracts. It is found in many parts of Rajputana and the Central India States, chiefly in the form of scattered trees in fields and waste lands and along roadsides, bunds, and railway embankments.

In the United Provinces the most important babul tracts are in the dry southern districts. In the sub-Himalayan tract the tree occurs only in certain isolated localities. Under the policy of afforestation promulgated by the United Provinces Government in 1912, the reservation of tracts of babul forest or of land capable of growing babul was commenced a few years ago in the Hamirpur and Etawah districts, with the idea of being extended to other districts as further experience in methods of afforestation is gained. It has now been definitely proved by the Kalpi plantation in the Jalaun district and the Fisher forest at Etawah that ravine lands in the southern districts of these provinces can be successfully afforested with babul; the rainfall here is between 30 and 40 in. These plantations are referred to on pp. 437-440, under 'artificial reproduction'.

Central Provinces and Berar. In the Central Provinces proper *Acacia arabica* occurs for the most part on open cultivated or waste lands and grazing grounds outside the large forest tracts, usually frequenting black cotton soil or alluvial ground in the neighbourhood of streams: it is also frequently met with on bunds and embankments.

The most important babul tracts are found in Berar, where the State babul forests extend over about 15,600 acres, while an additional area of public land (grazing grounds, &c.), roughly estimated at 12,500 acres, either contains crops of babul or is capable of supporting them. The tree also occurs in considerable abundance over private lands, along boundaries between cultivated fields, along banks of streams, and elsewhere. According to Mr. Shrinivasulu Nayadu¹ the distribution of the babul in Berar is determined mainly by situation, soil, and altitude. The underlying rock consists throughout of Deccan trap, and there is a varying depth of black cotton soil over it. The topography of the country is characterized by three main features: (1) on the north the Gawilgarh hills (the Melghat), averaging 3,400 ft. in elevation; (2) on the south the Ajanta hill range (the Balaghat), comprising undulating plateaux about 1,600 to 2,200 ft. in elevation; and (3) between these two hill ranges the broad valley of the Purna river system, known as the Payanghat plain, 800 to 900 ft. in elevation. The Gawilgarh hills are unsuitable for babul, since even in the ravines and valleys the substratum is dry, while frosts of some severity occur: the rainfall here is about 58 in. In the Balaghat babul

¹ *loc. cit.*, p. 491.

occurs to a greater or less extent along the banks of streams, and on cultivated and other land where there is sufficient immunity from frost and weeds : the rainfall of this tract averages 38 in.

The Payanghat plain is the important babul-bearing tract of Berar, and it is here that most of the State babul *bans* are situated. In this plain overlying the Deccan trap is a deep alluvial deposit, often 150 ft. in depth. Black cotton soil occurs at the surface, with yellow calcareous loam beneath ; this loam often appears at the surface, and is less favourable to tree growth than the black cotton soil. Deposits of silt are frequent in the river valleys and along the sides of streams. The water-bearing stratum is at a considerable depth, but the superficial strata are sufficiently retentive of moisture to support the growth of babul. The rainfall in the Payanghat tract averages 30 in., rain falling mainly during the south-west monsoon from June to September, with occasional showers from November to January. Frost is of rare occurrence ; indeed, wherever it occurs in Berar the babul is easily capable of standing the winter cold, suffering only in abnormal years, as in January 1911. Babul forms about 90 per cent. of the tree growth of the Payanghat, its chief companions being *Acacia leucophloea*, *A. eburnea*, *Prosopis spicigera*, *Dichrostachys cinerea*, *Balanites Roxburghii*, *Azadirachta indica*, *Zizyphus Jujuba*, and *Phoenix sylvestris*. Common species of the undergrowth are *Cassia Tora*, *C. auriculata*, and *Capparis grandis*. In situations favourable to the babul this tree forms pure crops, the associates becoming more prominent where the black cotton soil gives place to calcareous loam or shallow soil. *Phoenix sylvestris* predominates on swampy ground. Babul occurs most plentifully and shows the most vigorous growth in the deep moist soil in the neighbourhood of streams and particularly along the Purna river : in such places it benefits by the annual inundations during the rainy season. Both the *telia* and the *kauria* varieties are common, the former seeking the localities with deep moist soil and the latter being more plentiful on the higher and drier ground away from the streams, or where there are calcareous deposits near the surface, or where the salinity of the soil becomes marked : the growth of the *kauria* is much slower than that of the *telia* variety, and the rate of growth of the latter decreases away from the streams.

Bombay Deccan. The principal babul tracts of the Bombay Deccan are situated in the Khandesh, Nasik, Ahmednagar, Sholapur, Poona, and Satara districts. The actual area of these tracts is difficult to estimate, as the babul is restricted to certain localities and is not distributed over the whole forest area. In 1908 the total area of State babul forests was estimated at 45,000 acres. The forests are for the most part widely scattered over cultivated lands, usually in isolated patches of comparatively small size, and along the banks of rivers. The underlying rock is mainly trap, over which there is frequently a varying depth of black cotton soil favourable to the growth of babul, but on the higher ground away from rivers the soil usually becomes a dry shallow *murram*, the result of the disintegration of the trap, or a calcareous *kankar* unfavourable to babul. The best babul tracts are invariably situated on deep sandy alluvium along the banks of rivers and streams subject to annual inundation. Here the *telia* variety flourishes and often forms dense crops. On the deep black cotton soil of the lower ground the babul also

flourishes well, but on the higher ground away from the rivers, where the soil is dry and shallow, the *teli*, variety gives place to the *kavadi* (*kauria*), the crop becomes more open and the trees are stunted; finally on the poorest localities, where the soil consists of deposits of *kankar*, the babul may disappear altogether and give place to *Acacia eburnea*, *A. Latronum*, *A. Catechu*, *Balanites Roxburghii*, *Capparis aphylla*, and occasionally *Azadirachta indica* and a few other species. These species are characteristic of the poorest types of babul forest. Among other associates on comparatively dry ground are *Zizyphus Jujuba*, *Prosopis spicigera*, *Albizia odoratissima*, *Diospyros Melanoxylon*, *Acacia leucophloea*, *Anogeissus latifolia*, and others, while on the rich alluvium along the rivers *Pongamia glabra* and *Eugenia Jambolana* make their appearance. The babul crops occur in various stages of development: under previous working plans most of the old and deteriorating trees have been cut out, and the majority of the more promising crops are of various ages up to 20 or 30 years.

The climate of this region is a dry one, the rainfall, which is uncertain, varying from 18 to 30 in., though the tree thrives best where the rainfall is over 25 in. The absolute maximum shade temperature varies from 108° to 112° F., and the absolute minimum from 37° to 45° F. From March to May there is intense heat and drought, which is detrimental to reproduction and development on all but the deeper and richer soils where the roots are able to penetrate to the moist strata: the annual inundations on the alluvial riverain tracts are therefore of the greatest importance in producing favourable soil conditions to counteract the adverse climatic factors.

Southern India. The babul is found in greater or less abundance in suitable localities throughout the plains in the drier parts of the Madras Presidency, Hyderabad, Mysore, and Travancore, where the rainfall varies from 20 to 40 in., but not in the moist regions of the west coast. In Madras it occurs in fair abundance in several districts, particularly in Kistna, Kurnool, Anantapur, Guntur, Bellary, Chingleput, and Tinnevely. It is usually found on black cotton soil, but also occurs on other soils, for example on ferruginous loam overlying metamorphic rocks in Bellary, where it is stunted and much damaged by grazing. In some districts, particularly in Tinnevely, good crops of babul are found in the beds of numerous tanks scattered about the country. Many of these have been formed into reserved forests and improved by artificial sowing; they constitute an important source of supply of fuel and agricultural and domestic timber. Among the more usual associates of the babul in Madras are *Acacia planifrons*, *A. Latronum*, *A. leucophloea*, *Prosopis spicigera*, *Cassia Fistula*, *C. auriculata*, and *Azadirachta indica*.

LEAF-SHEDDING, FLOWERING, AND FRUITING. *Acacia arabica* is hardly ever quite leafless, though on very poor soils it is sometimes bare for a short time in April-May. The young leaves appear from March to May, the old leaves commencing to fall before they appear and continuing to do so while the young leaves are sprouting. The flowering season is somewhat irregular, varying not only according to locality but also in the same locality. Flowering is most general in the rainy season, from June to September or October, but trees may be found in flower as late as December or January. The flowers are in fragrant yellow globose heads about 0.5 in. in diameter. The young

fruits develop rapidly ; the time of ripening varies according to locality, but is usually from April to June, or earlier in southern India. In the Peninsula the *kauria* variety is said to ripen in January and February. In Sind the tree flowers as a rule twice a year, once in June-July and again in November-December. The pods from the first flowering ripen about October, but are usually poor in quality and quantity : those of the second flowering ripen about May, and as a rule give a better crop. The pods (*telia* or typical variety) are 3-6 in. long by 0.5 in. broad, compressed, whitish tomentose, deeply constricted between the seeds, eight- to twelve-seeded. In the *kauria* variety the pods are more shortly stalked, about 0.75 in. broad, and very little constricted between the seeds. The seeds (Fig. 161, *a*) are compressed, ovoid, dark brown, shining, with a hard testa ; about 200 to 300 weigh 1 oz. They retain their vitality for some years if carefully stored. They are liable to beetle attacks even when still on the tree.

Trees commence to bear fruit at an early age, usually at about five to seven years or somewhat later in Sind. They seed annually as a rule : in Sind the crop of pods is sometimes affected if the winter is severe, but this is not frequent. The pods are usually blown from the trees by the dry winds of the hot weather. They dehisce with difficulty, and if not eaten by animals may lie on the ground until the valves rot, the seed remaining ungerminated until it escapes in this way, though it is exposed in the meantime to the attacks of insects, rats, and squirrels. In exceptional cases the seeds may germinate inside the decaying pod, a line of germinating seeds being found partially enclosed in the pod : such cases are rare. Seed may be removed from the pods by drying the latter and pounding them. In tests of Berar seed carried out at Dehra Dun in 1911 and 1912 the *telia* variety gave the highest percentage of success, the *kauria* came next, and the *ramkati* gave the lowest percentage.

The pods are readily eaten by sheep, goats, and cattle, and the seeds are ejected by them. As far as recorded observations go the seed, although it does so in the case of bovine animals, seldom passes completely through sheep and goats, but is ejected by them from the mouth during rumination ; the seeds are, it is true, found among their droppings, but this is because of the fact that rumination ordinarily takes place where the animals are herded. The fermentation and moistening which the seeds undergo before their ejection undoubtedly assists germination, and seed which has been ejected by animals is also held to be less liable to insect attacks than seed collected straight from the pod. The superiority of seed collected from goat and sheep pens is generally recognized, and seed so collected is extensively used for artificial sowings.

Experiments carried out in Sind in 1910-11 and 1911-12 to test the fertility of seed obtained from goat and sheep pens and those obtained direct from pods gave the following results :

	From pens. per cent.	From pods. per cent.
Sukkur division	13	6
Hyderabad division . . .	56	43
Naushahro division . . .	70	35
Jerruck division	51	31

An experiment in the Sukkur division to ascertain if the fertility of seed is impaired by prolonged immersion in water showed that immersion extending

up to five weeks had no harmful effect, a fact which is of importance in tracts inundated for some time.

GERMINATION (Fig. 161, *b-d*). Epigeous. The radicle emerges and descends. The hypocotyl elongates, arching very slightly or not at all, and raises the cotyledons above ground; as a rule the testa is carried up over the cotyledons, falling with their expansion.

THE SEEDLING (*telia* variety, Fig. 161).

Roots: primary root long, thick in vigorous plants, otherwise thin and wiry, terete, tapering, light brown: lateral roots numerous, short, fibrous: small nodules present. **Hypocotyl** distinct from and thicker than young root, 0.7–1.3 in. long, terete, cylindrical or tapering slightly upwards, expanded in a ring at the base, pale green, glabrous. **Cotyledons**: petiole 0.1 in. long, thick, glabrous: lamina 0.5 in. by 0.4 in., plano-convex, fleshy, less than 0.1 in. thick, elliptical or ovate, apex rounded, base sagittate, entire, glabrous, pale green beneath, darker above. **Stem** erect, somewhat zigzag at the nodes, wiry, pale green, glabrous: internodes variable in length, usually 0.2–0.4 in. long in young seedlings. **Leaves**: first pair opposite or sub-opposite, subsequent leaves alternate. Stipular spines in pairs at the base of the leaves at first 0.1 in. long, increasing to 0.5 in. long after a few nodes. First pair of leaves paripinnate, up to 1 in. long, with about four pairs of leaflets 0.1–0.2 in. long, or second leaf sometimes bicompond, subsequent leaves bicompond, first with one pair then with two pairs of pinnae, the number of pinnae increasing subsequently.

Under favourable conditions the development of the seedling is rapid from the commencement, plants which germinate about July sometimes reaching a height of 3 to 4 ft. by December. Experiments carried out at Dehra Dun indicate that the chief factors stimulating rapid development are an abundance of light and a loose soil free from weeds: irrigation also stimulates growth, but in the seedling stages weeding and loosening of the soil are even more important. The climate of Dehra Dun, it may be noted, is damper than in any region where the tree grows naturally. The development is poor on stiff clay. Experimental plots at Dehra Dun, some weeded and others not weeded, some irrigated and others not, showed the following rate of growth during the first season in respect of the three varieties of babul:

Acacia arabica: growth of seedlings under different conditions, Dehra Dun.

Variety.	Particulars.	Irrigated.		Unirrigated.	
		Weeded.	Unweeded.	Weeded.	Unweeded.
<i>Telia</i>	Number of plants at end of season	99	15	28	12
	Height . . .	0 ft. 3 in.–2 ft. 0 in.	0 ft. 2½ in.–1 ft. 0 in.	0 ft. 9 in.–3 ft. 6 in.	0 ft. 2 in.–1 ft. 1 in.
	Condition . . .	Chiefly vigorous	Weakly	Chiefly vigorous	Weakly
<i>Kauria</i>	Number of plants at end of season	36	80	38	2
	Height . . .	0 ft. 1½ in.–3 ft. 8 in.	0 ft. 3 in.–2 ft. 0 in.	0 ft. 3 in.–3 ft. 6 in.	Larger 0 ft. 11 in.
	Condition . . .	Chiefly vigorous	Weakly	Chiefly vigorous	Weakly
<i>Ramkati</i>	Number of plants at end of season	16	2	29	12
	Height . . .	0 ft. 10 in.–4 ft. 3 in.	0 ft. 3 in.–0 ft. 5 in.	0 ft. 3 in.–4 ft. 0 in.	0 ft. 2½ in.–0 ft. 11 in.
	Condition . . .	Vigorous	Weakly	Vigorous	Weakly

Approximately the same quantity of seed was sown in each plot, but the number of seeds sown was not recorded.



FIG. 161. *Acacia arabica*- SEEDLING $\times \frac{3}{4}$

a Seed b-d Germination stages e-h Development of seedling during first season

These results demonstrate the great importance of weeding, irrespective of irrigation.

During the first four years the maximum height of a plot of seedlings at Dehra Dun from seed sown in 1911 was as follows :

End of first season ; maximum height 1 ft. 7 in.

End of second season ; maximum height 6 ft. 8 in.

End of third season ; maximum height 15 ft. ♦

End of fourth season ; maximum height 16 ft., girth 9 in.

This plot was regularly weeded, but not watered, and the soil was a deep loam.

The influence of a loose porous soil on the development of the seedling is well illustrated in the case of sowings where the seeds are sown along ridges of loose earth. This system has been found very successful in dry localities ; vigorous plants raised in such sowings have thick stems and strong side branches, and may reach a height of over 4 ft. in the first season, whereas seedlings from sowings on level ground in the same place may attain a height of not more than a few inches, without well-developed side branches, and in many cases are unable to survive the ensuing dry season. A feature of the babul seedling is the long taproot, which is developed at an early age, and is a necessary provision in the dry localities in which the tree grows, and particularly on black cotton soil, which is sodden in the rains and dry and cracked in the dry season. A vigorous plant on a weeded ridge sowing of June 1914 in the Hamirpur district, United Provinces, was dug up in December 1914 and found to have a taproot 5 ft. long and $\frac{1}{2}$ in. thick at the top.

The seedling is a strong light-demander, and will not tolerate suppression of any kind. In experimental sowings at Dehra Dun under different degrees of shade it was found that the development was always better in full sunlight than under even the lightest shade. In groups of seedlings the stronger individuals quickly suppress the weaker ones and kill them out.

During germination the radicles are very liable to damage by insects in the case of seed lying on the surface of the ground. Another serious cause of mortality is the damping off of young seedlings in sodden grass or weeds during the rains. In inundated tracts, as in Sind, seedlings are sometimes killed by an excess of water in low-lying areas where the flood water lies for some time after the end of the season. The seedlings are decidedly tender to frost : in Dehra Dun the *telia* variety was found to be somewhat hardier than the *kauria* in this respect, and seedlings on clear weeded ground suffered less than those growing in grass. Young plants, however, have good recuperative power from the effects of frost, sending out new shoots after being killed back. In dry climates drought is undoubtedly the most serious cause of mortality among seedlings ; the *kauria* variety is more drought-resistant than the *telia*.

The young plants are also subject to injury from animals : the spines which are developed at an early age ordinarily protect them from damage by domestic animals other than browsers, of which goats are the worst. They are frequently browsed by deer and antelopes and eaten by hares. The most serious animal pest, however, is the Indian gerbille or antelope rat (*Gerbillus indicus*), which gnaws the bark of the seedlings, or cuts through the shoot or root. Mr. Shrinivasulu Nayadu¹ states that the injury begins when the

¹ *loc. cit.*, p. 500.

seedlings are weeded in the rains, but becomes very noticeable when the harvest is over and there is no food in the fields to invite the rats. These animals appear to multiply most freely in dry seasons, heavy rain being injurious to them. The deep cracks in the black cotton soil are specially favourable to them, since they live in deep burrows. The rats rear their young, eight to twelve at a time, in nests built about 2 ft. above ground in the interlaced branches of babul thickets, and a knowledge of this fact is useful in helping to reduce their numbers.

SILVICULTURAL CHARACTERS. *Light.* *Acacia arabica* is a strong light-demander, and will not tolerate suppression of any kind at any period of its existence. Young natural crops are often dense, and for some years the saplings may grow up without many side branches, but they thin each other out and the trees develop broad and full though somewhat light crowns. When grown in a free position the tree maintains a bushy form for many years, though the main stem is distinguishable.

Root-system. The young plant, as already mentioned, develops a long taproot from the commencement, and strong lateral roots are also formed early. The subsequent development of the root-system depends to some extent on the locality. Under normal conditions on dry ground the taproot reaches a considerable length. Mr. Ribbentrop states:¹ 'I have known them to be 25 ft. long, and under certain conditions they may reach much lower.' In addition to the taproot a strong superficial root-system is produced. On shallow soil the taproot branches without reaching any depth, and the plant is liable to die of drought. On inundated land the root-system is largely superficial.

Root-suckers. The babul has not as a rule been observed to produce root-suckers regularly, but Mr. A. W. Lushington says:² 'When pulling up what appeared to be seedlings of babul (*Acacia arabica*) in the Kistna district, they were found not to be seedlings at all, but sucker-shoots.' He mentions further that these suckers are produced especially when trees have been felled or where the roots have been exposed, and that he has found that a very fair percentage of what he always supposed to be seedlings have been these sucker-shoots. Mr. P. M. Lushington,³ writing of babul areas in the Guntur district, Madras, says: 'Hitherto I have believed that the coppice resulting from babul was practically unproductive, and have for many years advocated the wounding of the roots with a view to producing root-shoots.' The Deputy Conservator of Forests, Sind circle, wrote in 1911: 'Experience here tends to show that babul has very limited powers of reproduction by coppice-shoots or root-suckers.' Other writers have expressed doubt as to the capacity of the tree for producing root-suckers. So far as observations go at present, therefore, it may be considered as established that the babul, though it may not produce root-suckers universally, does produce them in some localities and under certain conditions, this tendency being stimulated if the trees are felled or the roots exposed.

Coppicing power. The coppicing power of the babul varies greatly. Throughout the greater part of its habitat it coppices poorly; this, from

¹ Ind. Forester, xxv (1900), p. 136.

² Ibid., xxx (1904), p. 163.

³ Inspection note, 1912-13.

observations recorded by numerous forest officers, appears to be the case in Sind, Berar, the Bombay Deccan, and many parts of southern India, for although stumps up to about 6 or 7 in. in diameter frequently produce coppice-shoots, these in the majority of cases do not develop, remaining small and bushy or dying off altogether. Larger stumps cannot be relied on to produce coppice-shoots, and in general coppice as a regular means of reproduction is held to be out of the question.

Certain important exceptions have, however, been recorded, notably from Guntur in the Madras Presidency, where the babul has been regularly worked under the coppice system for some years. Mr. P. M. Lushington, after inspecting one of the babul tracts in Guntur, wrote: 'Hitherto I have believed that the coppice resulting from babul was practically unproductive. . . . A glance at this area was sufficient to show me that my opinion was unsustainable. Here we have a well established working series in which coppice reproduction is the main feature. The working is fully justified by results, for I saw established coppice seven years old which, though it did not cover the whole area, was well on its way to establishing a fairly thick forest.' Other recorded observations indicate that in certain parts of Madras, at all events, coppice reproduction can be relied on to a fair extent provided the trees felled are not of large size.

The precise reason why babul coppices in some localities and not in others has not yet been satisfactorily explained. That flooding, provided it is not of excessive duration or intensity, is a possible factor is indicated from the observations of Mr. J. S. Scot, who notes that all the best coppice areas in Guntur are those which are under water for some period each year.¹ There must, however, be other factors at work, otherwise the babul in Sind would coppice freely.

Pollarding. The babul usually pollards well, and is freely lopped for thorn fences and fodder.

Susceptibility to injuries. (i) *Storms.* Trees on inundated ground which has become soft are liable to be uprooted on an extensive scale; this is particularly the case in Sind. Where the fungus *Fomes Pappianus* is prevalent trees are frequently uprooted owing to decay in the roots, or the stems or large branches may be snapped in two owing to the brittleness of the affected wood.

(ii) *Frost and drought.* The tree is frost-tender, but is drought-resistant so long as the subsoil moisture holds out. The mortality among trees in Sind after the land ceases to be regularly inundated has already been referred to. In Sind damage by frost is less severe on inundated lands than on lands which have passed beyond the stage of annual flooding.

(iii) *Fire.* The babul is not a fire-resistant species, and is often killed outright where much inflammable grass is present.

(iv) *Animals.* Among grazing animals goats and camels are the most destructive, and sheep and buffaloes are also harmful. Cattle are the least harmful, and may even be beneficial, if admitted in small numbers, in keeping down grass and weeds and thus reducing the cover for rats and hares and the amount of inflammable material. Damage to young plants by deer, antelopes, hares, and rats has already been referred to.

¹ Ind. Forester, xxxviii (1912), p. 396.

(v) *Insects*. The two most destructive insect pests of the babul are the beetles *Coelosterna scabrata*, Fabr., and *Psiloptera fastuosa*, Fabr., an account of which by E. P. Stebbing is contained in *Forest Bulletin* No. 12 of 1912. The former, which is the more dangerous of the two, is a root-boring longicorn, the grubs of which tunnel in the roots and kill young trees: the imago strips the bark from the leading shoots and branches of young trees. The latter beetle is a buprestid, which as far as is known attacks trees only in its mature stage, stripping the bark off the shoots and branches.

(vi) *Fungi*. Much damage is caused in Berar by the fungus *Fomes Papianus*, Bres. This fungus attacks the heartwood of the stem and branches and spreads into the roots, causing the wood to become brittle, and in severe cases to crumble away: infected trees are thus liable to be blown over or to have their stems and branches snapped in two by wind. The fungus does not attack young healthy trees, but only those which are in an unhealthy condition or have ceased to grow vigorously owing to injury or to old age: it attacks isolated trees as well as those growing in dense crops. It has not yet been ascertained whether the fungus spreads underground through the roots by means of mycelia or through wounds above ground by means of spores, or both.

Measures which have proved efficacious in keeping the fungus in check are: (1) to remove all sporophores from infected trees; (2) to cut out badly infected trees; (3) to execute regular thinnings in young crops, removing sickly stems and promoting vigorous growth in those retained; (4) to cultivate the soil with field crops after the babul crop has been removed, and to keep the young babul crop healthy by hoeing the ground and promoting soil-aeration.

(vii) *Lopping*. Lopping for fodder and thorn hedges is a source of much injury to the babul: in some cases the lopping takes the particularly destructive form of half cutting through the branches and bending them down to be within the reach of goats and cattle, a jagged wound being thus formed: small trees are similarly cut half through a few feet from ground-level and broken down. Although the babul has great capacity for healing wounds, jagged wounds formed by rough methods of lopping do not heal, and become centres of infection by rot. It is by no means improbable that lopping may prove to be one of the chief causes of the spread of fungus attacks.

NATURAL REPRODUCTION. Under natural conditions germination commences early in the rainy season and continues for some time. Much moisture and warmth are necessary to effect complete germination, and without these the seed may lie dormant for two seasons or more and then germinate if conditions are favourable. Experiments at Dehra Dun in which seed was sown under varying degrees of shade and temperature showed that germination was considerably retarded under even slight shade, owing to the reduction of temperature, and that when it did take place the seedlings were unable to persist for any length of time in the absence of complete light.

The dangers to which the seedling is exposed during and after germination have been mentioned above under 'the seedling', and these are all factors inimical to natural reproduction.

1. It may be said generally that the conditions essential for the stimulation of vigorous natural reproduction are: (1) complete sunlight, (2) abundant

moisture, (3) loose soil, and (4) absence of grass and weeds. Apart from these factors germination is greatly stimulated if the seeds have been swallowed by animals and ejected by them.

The effect of complete light may be seen in any babul tract. Successful reproduction never appears under or even close around seed-bearers, but always in open gaps fully exposed to light. The effect of abundant moisture is seen in riverain tracts, where successful reproduction depends largely on the extent of the annual floods, failure usually following abnormally dry seasons. In tank beds in Madras it is noticeable that natural reproduction is most plentiful where the ground is annually inundated and scanty on the higher ground. Seedlings are, however, sometimes killed out by excessive flooding, not only in riverain tracts but also in depressions on flat ground. In riverain tracts it is probable that considerable loss is caused by seeds and seedlings becoming buried in thick deposits of silt.

The effect of loose soil is most marked, since it has a direct influence on the development of the taproot, and causes soil-aeration and the retention of soil moisture. For this reason vigorous natural reproduction frequently springs up on ploughed land and on new embankments, while on hard unworked ground reproduction is usually scanty or absent. The presence of rank grass and weeds is one of the factors most adverse to the establishment of natural reproduction, babul seedlings being particularly sensitive to suppression. In this respect grazing is advantageous in keeping down a rank growth of grass. One of the worst weeds in babul tracts of the Peninsula is *Cassia Tora*, which sometimes forms a dense soil-covering and effectually prevents reproduction.

The importance of animal agency in promoting the germination of the seeds has already been alluded to. Apart from this grazing animals perform a most useful function in spreading the seed over ground on which they are herded, and which is usually kept free of grass and weeds. Both in inundated riverain tracts and on other lands subject to grazing the seed is brought on to the ground very largely by animals, and the existence of many babul groves may be traced directly to their agency. The young seedlings as a rule require protection from cattle only for about six months or less, but protection from goats is necessary until the plants are well out of their reach.

A consideration of the factors just enumerated does not, however, always solve the question of natural reproduction, the presence or absence of which in patches of varying extent for no apparent reason is not always easy to account for. Thus good patches of even-aged reproduction frequently occur in places where attempts to regenerate artificially by scattering seed on the ground have resulted in failure, and this would indicate that there may be special reasons for such natural reproduction establishing itself only under certain favourable conditions, whether seasonal or otherwise.

ARTIFICIAL REPRODUCTION. The choice between direct sowing and transplanting from the nursery is easily decided, for owing to the sensitive-ness of the taproot transplanting on a large scale is out of the question for forest purposes. Numerous transplanting experiments at Dehra Dun, in which roots and stem were in some cases pruned and in others left intact, resulted in almost complete failure. Only when very small plants of the first season were transplanted early in the rains with great care, and watered in dry weather,

was even slight success attained. On a large scale the cost of such operations would be prohibitive considering the proportion of failure likely to be met with.

Direct sowings, however, are very successful, provided certain precautions are observed. The chief of these are as follows :

1. *Choice of site.* In arid climates, as in Sind, the formation of plantations is useless unless natural or artificial irrigation can be secured. It is doubtful if plantations could ever be profitable in regions with a rainfall of less than 20 in., except on deep rich moist soil, such as that found along the sides of rivers and streams. In any locality sowings on poor shallow soil such as *kankar* deposits will never produce anything but poor stunted growth ; babul sowings should be confined to the more fertile ground, the poorer soil being reserved for neem (*Azadirachta indica*), *khair* (*Acacia Catechu*), and other trees which are not exacting. Localities subject to severe frost should be avoided.

2. *Treatment of soil.* Except in certain flooded riverain lands, thorough loosening of the soil and removal of matted grass roots are necessary for the success of babul sowings ; not only is this the case before the seed is sown, but in places where the soil is apt to cake or crack it is also necessary subsequently, and can be effected, where the soil is not too stiff, by means of hand ploughs. In black cotton soil it may be necessary to fill up the cracks which form in the dry season.

3. *Preparation of seed.* Where possible seed collected from sheep and goat pens should be employed, as this germinates more quickly and gives a higher percentage of success. Failing this a common practice is to soak the seed in water or heap it up with moist cow-dung to stimulate germination.

4. *Weeding.* Although exceptional cases occur where weeding is found to be unnecessary, as in the flooded riverain tracts of Sind, as a general rule systematic weeding of the young crop for the first two or three years is essential.

5. *Thinning.* In the United Provinces and Berar it has been found of great advantage to commence thinning out the young plants in the first year and to continue annual thinnings for a few years, followed by periodical (usually 5-yearly) thinnings later. The early thinnings consist in spacing the plants in such a way as to prevent contact of the branches.

6. *Admission of grazing.* In some localities grazing of all kinds is excluded during the earlier years of the plantation. In Berar, on the other hand, success has been found to depend largely on the admission of light grazing by cows and bullocks (not sheep and goats) from the end of the first rains onwards, in order to keep down the growth of grass, which harbours rats, hares, and beetles, and also suppresses the seedlings. In order to secure the utmost benefit from grazing, the lines are widely spaced, usually 12 ft. apart, the plants are regularly thinned, and their lower branches are pruned in order to allow the cattle to obtain access to the grass between the plants.

Various examples of sowings in different localities are described below. The method of sowing must necessarily vary under different conditions, but it has now been conclusively proved that in dry regions on non-irrigated culturable land the method which has succeeded best, and is also very cheap, is that of line sowings in conjunction with the raising of field crops, which has been practised on a considerable scale in Berar. The ridge sowings employed

in the United Provinces in the Hamirpur district and elsewhere also give good promise of success, though they are somewhat costly.

Experimental sowings at Dehra Dun. In numerous experimental sowings carried out at Dehra Dun it was found that both irrigated and unirrigated line sowings on loosened soil succeeded well, provided the lines were kept thoroughly weeded and the soil was worked up periodically along the lines. Wherever weeds were allowed to get the upper hand the babul was killed out by the middle of the second season. In the irrigated line sowings the seed was sown along the base of the ridge of earth thrown up alongside an irrigation channel 1 ft. wide and 9 in. deep. Unirrigated line sowings along with field crops were found to give excellent results where the seed was sown along a loosened strip 2 ft. wide kept clear of crops, the crops being sown in the intervening spaces. Where the crops were sown continuously over the area the young babul plants were suppressed and killed out. Thorough weeding and periodical loosening of the soil along the lines were found to be necessary for satisfactory development. One pound of seed was found sufficient for 270 ft. length of line. The field crop employed was the lesser millet or *mandwa* (*Eleusine coracana*, Gaertn.), which was sown early in June and reaped in October.

Berar : agri-silvicultural sowings. The sowing of babul in conjunction with the raising of field crops has been carried out systematically in Berar for several years past, and has proved much more successful and economical than any other form of artificial reproduction ; efforts are therefore constantly being made to extend this method of reproduction and popularize it among cultivators.

Under the Berar system the coupe of the year is auctioned, the purchaser being required to grub up the stumps after felling the trees, and to cultivate the land with field crops under a lease. Cultivation with field crops alone is carried out for two successive years, and in the third year babul seed is sown in lines with cotton as the intervening field crop. The two years' preliminary cultivation is considered necessary (1) to enable the lessee to recoup the cost of digging out the roots of the felled trees, (2) to ensure the thorough cleaning and aeration of the ground, and (3) to remove all traces of the fungus *Fomes Pappianus* in the soil. The babul seed employed is that which has been swallowed and ejected by goats ; it is collected free of charge by the lessee. In the earlier sowings the lines of babul were sown 6 or 7 ft. apart, with three or four intervening lines of cotton ; this distance between lines was found to be too close to admit of the light grazing necessary to keep down the growth of grass after the removal of the field crops, and the distance now commonly adopted is 12 ft.

The lessee is required to weed the lines of babul thoroughly and to exclude goats from the area after the babul seed is sown. Provided he abides by the conditions of his agreement the lessee is allowed to retain possession of the area, free of assessment, until January of the year following the sowing of the babul, and is then rewarded at the rate of Rs. 2 per acre fully stocked with babul, suitable deductions being made for failures. The area is then taken over by the Forest Department and at once opened to light grazing of cows and bullocks—one animal per two acres—during the rainy season, in order to keep down the growth of grass and weeds. In places where growth is slow

or failures have occurred, or where there is a danger of the young plants being overtopped by a rank growth of grass, the lessee is permitted to cultivate for a fourth season on condition that he weeds the lines of babul and sows seeds wherever the first sowings have failed.

An important modification has been introduced in certain localities in order to combat the ravages of the beetle *Coelosterna scabrata*. This insect in the imago stage finds harbourage in grass and weeds, and hence the ground requires to be kept clear of such growth for as long as possible. This is effected by permitting the lessee to cultivate between the lines of babul for as long as he wishes, provided he weeds along and between the lines and prunes off the lower branches of the babul to give cattle access to the lines. A further precaution adopted is to sow neem (*Azadirachta indica*) seed along with the babul in the proportion of one of the former to three of the latter : the two species grow well together.

Thinnings are considered essential for the healthy development of the crop. The young plants are thinned out annually during the first few years, until they are as far apart as the distance between the lines, and thereafter at intervals of five years. The pruning of side branches is also carried out.

This system of cultivation promotes vigorous growth, the thorough working of the soil and the weeding causing the babul roots to strike deep down from the commencement. A height of 4 to 8 ft. is attained in two years on deep moist soil, and in three years on drier and poorer ground. It is proposed to work the plantations on a rotation of twenty or twenty-five years in order to supply timber as well as fuel.

Berar : broadcast, mound, patch, and strip sowings. Apart from the agricultural method of raising babul plantations in Berar, the following methods have given satisfactory results, though the success has never been as great as that of sowing with field crops : ¹

1. Broadcast sowings at a cost of about 4 annas an acre have been successful on areas which flank small streams : elsewhere they have usually proved a failure.

2. Mound sowings have been made in areas subject to floods or in swampy or water-logged situations. Low mounds 6 in. high and 2 ft. in diameter, spaced 8 ft. by 4 ft., have given good results : the cost has not exceeded Rs. 3 per acre.

3. Patch sowings have been made in blanks amongst young growth of babul or other species already on the ground. Patches 2 ft. by 1 ft., dug and cleared of roots to a depth of 6 in. and spaced 8 ft. by 4 ft., have given good results : the cost should not exceed Rs. 2-8-0 per acre.

4. Strip sowings have been largely carried out. Strips 10 ft. apart are made by means of three confluent plough furrows, each strip being about 2½ ft. broad : the cost has been from Rs. 2-8-0 to Rs. 2-12-0 per acre.

In all these sowings success was found to depend largely on the admission of light grazing of cows and bullocks in order to keep down the grass ; as a rule no grazing was permitted during the monsoon in which the sowings were made, but from October onwards the admission of cattle commenced. Goats and sheep were rigidly excluded.

¹ Shrinivasulu Nayadu, *loc. cit.*, p. 491.

Bombay Deccan : agri-silvicultural sowings. Mr. L. S. Osmaston¹ has described the results of experiments in sowing babul and other species in the Bombay Deccan in dry localities where the rainfall is scarcely 20 in. He states that in his experience the only successful method of restocking the forests of these dry tracts is by sowing in conjunction with the raising of field crops : the crops employed here are chiefly sesamum, cotton, and the lesser hemp.

Operations are conducted where possible by lessees and not departmentally. A two years' lease is given, and two different methods have been tried :

1. In the first year the lessee is allowed to cultivate field crops, the tree seeds as well as field crops being sown in the second year, one line of tree seeds to three lines of field crops, the distance between the lines of tree seeds being about 4 ft. : the lines are weeded twice in the first rains.

2. Tree seeds are sown in the first year of the lease in broad strips 4 ft. apart—four lines 1 ft. apart—alternating with strips of field crops 8 ft. broad : the lessee cultivates field crops between the strips of tree seedlings in the second year of the lease, and also weeds and sows up blanks.

The first method had been tried only recently, but if experience in Berar holds for the Bombay Deccan, the distance between the lines of babul may be found too small. The second method promises well, but success must depend largely on favourable rainfall : babul seedlings 3½ years old had a maximum girth of 11 in. and a maximum height of 16 ft. In departmental sowings on this principle the cost of formation—including cost of collection of seed and weeding, but not of supervision—for the first three years amounted to Rs. 28-11-0 per acre : the receipts from the produce of the agricultural crops amounted to Rs. 32 per acre, leaving a profit of Rs. 3-5-0 per acre.

In the Poona district deep ploughing with broadcast sowing of seeds which have been swallowed and ejected by sheep and goats has proved fairly successful.

Sind : broadcast sowings with and without field crops. In Sind broadcast sowings are carried out to supplement natural reproduction on new riverain land subject to annual inundations. The seed is scattered on the water when the floods are subsiding and sinks into the ground.

Broadcast sowings in conjunction with the raising of field crops are carried out extensively on land above the reach of ordinary floods which is capable of being irrigated by lifts. The babul seed is sown broadcast along with the field crops in the first year ; in the second year the area is again ploughed up and a second field crop is sown together with more babul seed. The second ploughing seems to do little damage to the babul crop, the cultivator learning to avoid the patches of babul, and the results attained are highly successful. The cultivator pays the current rate of land revenue during the two years in which he cultivates, and is also bound to irrigate the young babul crop for a third year and to protect it by means of thorny hedges. These plantations are formed entirely free of cost.

United Provinces. The babul has played an important part in afforestation schemes in the southern and drier parts of the United Provinces, where

¹ Ind. Forester, xxxiii (1907), p. 265.

the normal rainfall varies from 30 to 40 in. The sowing of babul, chiefly on an experimental scale, has been carried out both on ravine land and on flat or gently undulating ground. The principal examples of the former are the Kalpi plantation and the Fisher forest at Etawah. The Piprayan plantation, about $4\frac{1}{2}$ miles south-east of the Ata railway station, furnishes a none too successful example of sowings on uncultivated but irrigable land. This land, 162 acres in extent, was acquired in 1905, with the view mainly of providing bark for the Cawnpore tanneries. The plantation has suffered from insufficient irrigation, combined with the effects of abnormal frost and drought.

More recent experiments have been carried out on black cotton soil in the Hamirpur district in localities where the normal rainfall varies from 33 to 38 in. These experiments are interesting as showing the excellent results attainable by sowing on raised ridges both on water-logged and on over-drained ground. Under this method trenches $1\frac{1}{2}$ ft. by $1\frac{1}{2}$ ft. in section and 10 ft. apart are dug, and the loose earth is heaped up in a ridge alongside the trench. The seed is sown along the top of the ridge in June, before the rains commence; weeding is carried out throughout the rains, and after the rains, when the soil dries and tends to cake, it is kept loose, cracks being filled up. The seedlings are thinned out from the earliest stage; at first they are pulled up by hand, and afterwards superfluous plants are cut down with pruning shears, the rule being to thin out to such an extent as to prevent the plants from touching each other. The weeding, loosening of the soil, and thinning promote vigorous development, and by the end of the first season the young plants reach a height of $1\frac{1}{2}$ to 2 ft. or more with long thick taproots and stout stems and branches. As a rule it is found that unless the plants have strongly developed side branches they are liable to dry up in the hot weather. In order to guard against frost the grass which springs up between the lines, and which intensifies the risk, is cut and sold after the end of the rains. Fig. 162 shows these ridge sowings during the cutting of the grass. The main objection to this form of sowing on continuous ridges is its high cost, which in the experimental stages amounted to Rs. 15 to Rs. 20 per acre with an additional Re. 1 for each weeding, or Rs. 6 for six weedings in the first year. It is believed, however, that the cost will be considerably reduced after further experience, and by making the ridges non-continuous, say 5 ft. lengths of ridge alternating with breaks of 5 ft. Ridge sowings have given good results in the Fisher forest at Etawah (see Fig. 163).

Other methods which have been tried in the same locality are sowing in mounds, broadcast, and in ploughed lines, pits, and patches: these have proved far less successful than ridge sowings. Mound sowings were found to be fairly successful, provided the mounds were high: they are cheaper than ridge sowings, costing Rs. 9 per 100 mounds, but when failures occur large gaps are the result. Broadcast sowings have been successful only on the higher ground, and the results are therefore patchy. The ground requires to be kept loose and the plants to be weeded and thinned, operations which are difficult under the broadcast system. Sowings in ploughed lines were likewise successful only on the higher ground, not on low ground. The lines tend to crack longitudinally after the rains, causing the death of some of the plants. Thorough weeding and thinning of the plants and loosening of the soil are

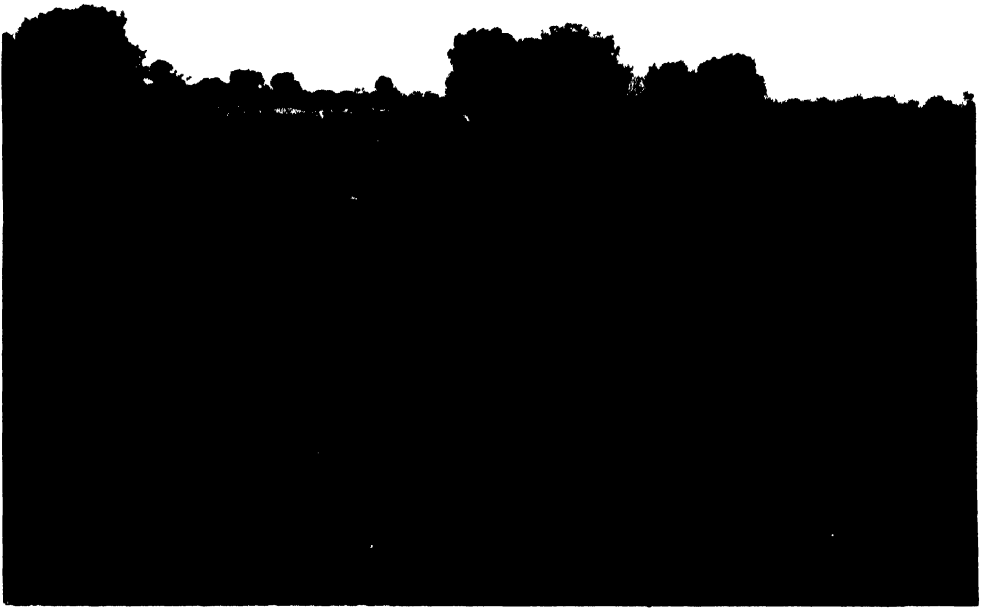


FIG. 162. *Acacia arabica*, weeded ridge sowings, end of first season, Hamirpur district, United Provinces. grass being cut between lines.

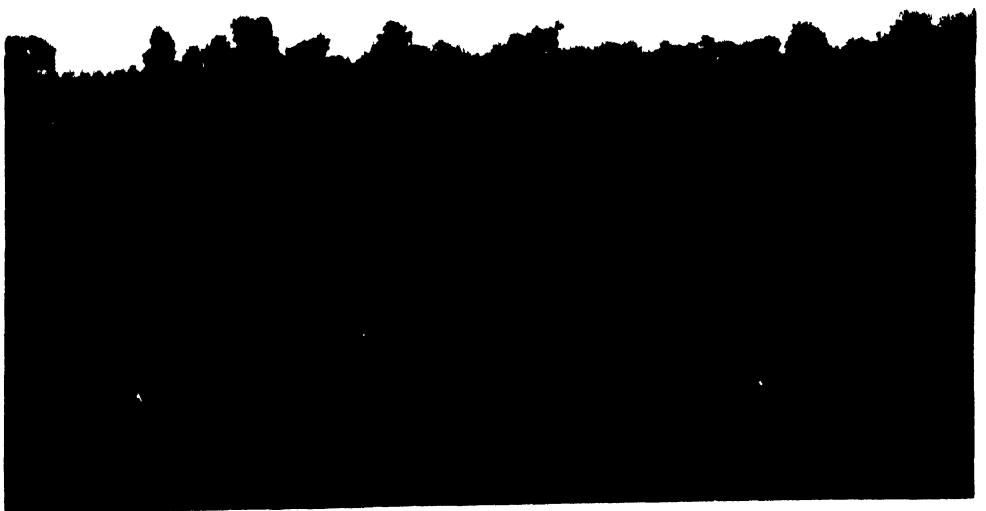


FIG. 163. *Acacia arabica*, ridge sowings in bed of stream, end of second year, Fisher forest, Etawah, United Provinces.



FIG. 164 Ravine lands being afforested with *Acacia arabica*, Kalpi, United Provinces



FIG. 165 *Acacia arabica*, sowings on ravine lands, Kalpi, United Provinces

necessary. Sowings in pits and patches proved an entire failure, the seedlings being swamped not long after germination.

Afforestation of ravine lands : the Kalpi plantation. The Kalpi plantation in the Jalaun district of the United Provinces was started in 1904 by the acquisition of 850 acres of ravine land, with the twofold object of producing supplies of babul bark for the Cawnpore tanneries and of ascertaining whether ravine lands could be successfully afforested with babul, in order to check the erosion to which these tracts are subject every year. Afforestation work was completed over the whole area in nine years.

This plantation may be regarded so far as purely experimental, but it has demonstrated that the ravine lands of the United Provinces can be successfully afforested with babul. The financial success of the plantation has not yet been assured, but this is due largely to the experimental character and therefore high cost of the work, and to a succession of abnormal years of frost and drought which greatly militated against success, and required the partial renewal of sowing operations over the same ground for a few years in succession. The plantation might have been more successful had closer supervision been possible, but as far as they go the results have been by no means unsatisfactory.

The preliminary work of reclamation of these ravine lands consists of breaking down the steep sides of the ravines into gentler slopes and constructing at intervals across the ravines bunds of loose earth with suitable outlets for water dug in the hard ground round their ends : these bunds are constructed at a comparatively cheap rate. This work is followed by the sowing of babul seed thickly along the bunds, on the sides of the ravines and on the elevated ground between them. The soil is extremely poor, with layers of gravel and *kankar*, the latter in particular hindering the development of the taproot. The sowings have proved particularly successful on the bunds of loose earth, which have become covered with dense promising crops of babul.

Apart from the bund sowings, which have always given the greatest success, three principal methods of sowing were tried :

1. Ploughing in strips with broadcast sowing. This was carried out in places where the ground was sufficiently level : strips were ploughed to a width of 3 or 4 ft., a distance of about four paces separating the strips, and seed was sown broadcast along the strips and covered by means of the agricultural *patra*. After the first year the width of the ploughed strips was increased to 5 or 6 ft. Ploughing was carried out at the commencement of and after the end of the monsoon rains, that is up to the middle of July and in September and October, and again during the winter rains in December and January. Thorough ploughing is necessary to eradicate the roots of grass and weeds.

2. Pitting. Where ploughing was impracticable, pits measuring $1\frac{1}{2}$ ft. in diameter and depth were dug at frequent intervals on contour lines, the loose earth being returned to the pits and the seed being sown on it : in the second year the size of the pits was reduced to 1 ft. in diameter and depth.

3. Lining. This was a modified form of pitting in which the lines consisted of elongated pits along the contour.

In each case the seed was sown at the beginning of the year, and at the end of the first season the success, particularly in the case of the sowings in ploughed strips and along contour lines, was decidedly promising. A year of abnormal frost and two years of abnormal drought, however, killed a large proportion of the young plants and seriously interfered with the success of the experiment. Indeed, throughout these sowings drought has proved the most serious source of injury, and success depends largely on years of good rainfall. The normal rainfall here is 32 in.

The sowings on the more level parts of the plantation have proved least successful, owing to the poverty and hardness of the soil, which increase the danger from drought. The whole plantation has been fenced and regularly fire-protected. The crop of grass which sprang up with the sowings necessitated careful weeding from the first season. It was sometimes found necessary to weed more than once during the first season, and the weeding was continued in subsequent years until the plants were well clear of grass and weeds. Hand-watering of the young plants was tried at one time, but had to be given up owing to its high cost. Fig. 164 shows the general aspect of the ravine lands in the Kalpi plantation, and Fig. 165 shows some of the results of the afforestation work.

More recent work in the afforestation of ravine lands in the Etawah district has given wonderfully successful results even on the most unpromising ground, where owing to the denuded and hardened condition of the soil the whole rainfall drains off rapidly. The subsoil water-level is at a great depth, and the upper strata of the soil are excessively dry. On such ground great success has been attained by deep ploughing, sowing of tree seeds in June, and repeated weeding and loosening of the soil. The first weeding is carried out soon after the first showers of rain, and two more weedings are carried out before the end of October, the soil being well loosened at the time of the last weeding. The ravines themselves are reclaimed by the construction of earth bunds at intervals across their beds, with the object of holding up silt, and the bunds and beds of silt are sown up. The sides of the ravines are afforested by means of a system of contour trenches and ridges on which sowings are carried out. Apart from *Acacia arabica* it has been found possible to raise crops of teak, *Dalbergia Sissoo*, *Gmelina arborea*, and other species on these ravine lands. The total cost of reclamation and afforestation amounts to between Rs. 50 and Rs. 60 per acre, inclusive of establishment charges and depreciation on plough bullocks and plant. The success of this work depends largely on the protection of the young plantations from grazing.

Experimental plantations on saline lands. Experimental plantations of *Acacia arabica* and *Prosopis spicigera* on salt-impregnated lands in the Aligarh district are described by Mr. G. Greig in the *Indian Forester*, vol. ix (1883), p. 454. Success was obtained by digging pits 3 to 4 ft. deep and filling them with good soil, in which young nursery-raised plants were planted. The seed was sown in the nursery early in June, the seedlings being pricked out 2 ft. apart in July, when about 4 in. high, and transplanted early in the rainy season of the following year, when about 2 ft. high, great care being taken to keep moist earth, bound on with grass, round the roots. Transplanting was

also found to be possible, if carefully done, in December and January. The plantations were regularly irrigated. Flooding was found to be injurious to the young trees; the best method of irrigation proved to be by means of small channels 1 ft. broad and 1 ft. deep running along the edges of the lines of trees, the water being allowed to stand in the channels for several hours and to percolate into the pits in which the trees were planted. Eleven acres of the Pardilnagar plantation, on strongly saline land, had been planted in this way eight or nine years previously, and some three-fourths of the area was densely covered with *Acacia arabica* trees 20 ft. or more in height.

SILVICULTURAL TREATMENT. *Clear fellings.* The system under which the babul is most commonly worked is that of clear-felling in equal annual coupes with artificial reproduction by sowing under one of the methods already described. This system is the one in vogue in Berar, the Bombay Deccan, Sind, and the United Provinces, the rotation ordinarily employed being 25 or 30 years in Berar, 30 or 40 years in the Bombay Deccan, and 30 years in Sind. Actually the rotation in Berar is two years shorter, the first two years being taken up with the cultivation of field crops prior to the sowing of babul. The tendency in Berar is to reduce the rotation, as experience has shown that after twenty years the babul is increasingly liable to fungus attacks. For the supply of tanning bark in the United Provinces a rotation of sixteen years is being adopted provisionally in afforestation schemes, though it is possible that in ravine lands it may be necessary to lengthen the rotation to twenty years. In Madras certain babul forests are worked under clear fellings, a few standards being sometimes left to provide natural reproduction.

In Sind the management is complicated by cyclones, drought, and erosion, and by the necessity for irrigation. The first three factors upset the working plans from time to time, necessitating the temporary suspension of regular fellings to provide for the removal of dead and fallen material. Special 'erosion fellings' are carried out to clear threatened banks in advance of the river's action, with the object not only of utilizing the trees but also of preventing the formation in the river of snags which endanger navigation. Irrigation schemes of considerable magnitude and complexity are also a special feature of the management of the Sind babul forests. Reproduction is not altogether artificial, a certain amount of natural reproduction being also obtainable; artificial sowings, therefore, though sometimes extensive, may be regarded as supplementary. A rotation of thirty years has been adopted primarily to meet the demand for fuel. The coupes are sold standing in August each year; the purchaser commences felling on October 1 or as soon afterwards as the floods subside, and completes felling and extraction by September 30 following, after which seed is broadcasted over the felled area.

Coppice-with-standards. In some parts of Madras, where babul of moderate size coppices without difficulty, the system of coppice-with-standards is followed; the standards left are few in number, and the coppice is usually worked on a rotation of fifteen to twenty years.

Thinnings. Practice as regards the conduct of thinnings varies in different localities. In Sind thinnings are not carried out. In Berar they are considered essential to the proper development of the crop. Regular thinnings

usually commence at an age of about ten years, and are repeated at intervals of five or six years; they are carried out with sufficient intensity to free the crowns of the trees from contact with each other. In the Bombay Deccan regular thinnings are also the rule.

Grazing. The question of closure to grazing has been carefully studied in Berar, and it is now recognized to be most beneficial to admit light grazing of cows and bullocks, one animal per 2 acres or sometimes up to one head per acre, as soon as the field crops are off the ground: this continues until the young crop is well established, that is for about five to seven years, after which the limit as to number is removed and buffaloes may also be admitted, but camels, goats, and sheep are excluded. In the Bombay Deccan closure to all kinds of grazing is prescribed for varying periods up to fifteen years or even more. In Sind the coupes are closed to all grazing for five years from the date of sowing, though in view of the rank growth of grass which springs up it would probably be beneficial to admit light grazing of cows and bullocks at an earlier stage: this is recognized, and actually closure is enforced for the first six to twelve months only. Browsers are not admitted until ten years after sowing, though it would be advantageous to exclude them for a longer period, if not permanently.

RATE OF GROWTH. The annual rings in *Acacia arabica* are indistinct, and much reliance cannot therefore be placed on the results of ring-countings. The rate of growth varies considerably, but under favourable conditions it is rapid. The following recorded measurements refer to various localities:

Punjab. Brandis¹ says that in the Punjab the tree attains a girth of 2½ ft. in about twelve years, and 5 ft. in about thirty years. Mr. Minniken reported that in the Delhi Bela plantation a girth of 2 ft. was attained in 7½ years.

Sind. Brandis¹ states that in lower and middle Sind the average girth at 4 ft. from ground-level has been ascertained to be 4 ft. in 35 years, and 6 ft. in 55 years. He also mentions that trees planted in 1844 at Jacobabad reached in less than 30 years a girth of 6–8 ft. and a height of 50–60 ft. More recent measurements in the Jerruck forest division² in annually inundated coupes of known age from 5 to 18 years old showed a mean annual girth increment of 1.73 in.: on alluvial land the age of which was approximately known the mean annual girth increment up to 40 years was estimated to be 1.67 in.

In the Hyderabad forest division measurements of trees of known age gave the following results:³

Age. years.	Diameter. in.	Corresponding girth.	
		ft.	in.
5	1.8	0	5.6
10	3.5	0	11.0
15	5.0	1	3.7
20	6.2	1	7.5

¹ For. Flora N.-W. and Central India, p. 182.

² Revised Working Plan for the Jerruck Forest Division, D. J. Navani, 1915.

³ Working Plan for the Hyderabad Forest Division, H. Mitra, 1900.

Bombay Deccan. In the Ahmednagar forest division the following has been estimated to be the average rate of growth, based on ring-countings : ¹

Acacia arabica : rate of growth, Ahmednagar.

Age. years.	Height. ft.	Diameter at base without bark. in.	Volume. cub. ft.
5 }	20-25	2.5	0.5
10 }		5.0	2.2
15 }	30-40	7.5	5.1
20 }		10.0	9.0
25 }	40-45	12.5	16.0
30 }		15.0	24.0
35 }	45-50	17.5	35.0
40 }		20.0	45.0

The following measurements are recorded in the Poona babul forest working plan,² though the working plan officer does not place absolute reliance on them since they are based on ring-countings :

Acacia arabica : rate of growth, Poona.

Age. years.	Mean radius.		Age. years.	Mean radius.	
	Above flood- level. in.	Below flood- level. in.		Above flood- level. in.	Below flood- level. in.
5	1.2	1.4	30	5.3	6.5
10	2.1	2.4	35	6.2	7.6
15	2.9	3.4	40	7.2	8.8
20	3.7	4.4	45	8.3	—
25	4.4	5.4	50	9.4	—

Berar. Mr. Shrinivasulu Nayadu ³ says that in Berar generally speaking a babul crop attains a height of 12 to 15 ft. in ten years, and estimates that with proper cultural attention babul crops ought to produce about 1 ton or 40 cub. ft. per acre per annum. In the Loni Bhongaon range working plan the mean annual radial increment is estimated from ring-countings to be 0.19 in., and the average yield of timber and fuel in existing coupes is estimated at 470 cub. ft. solid per acre.

Sample plot measurements extending over four years in the Akola forest division gave the following results :

Acacia arabica : rate of growth, Akola.

Plot No.	Number of trees measured.	Girths of trees measured. in.	Mean annual girth increment for 4 years. in.
1	27	30-56	2.0
2	15	16-46	1.6
3	13	15-30	0.94
4	13	15-33	0.9
5	6	24-50	1.2

¹ Working Plan for the Fuel and Fodder Reserves of the Ahmednagar Division, R. S. F. Fagan, 1901.

² Working Plan for the Poona Babul Forest, L. Napier, 1902.

³ *loc. cit.*, pp. 504 and 512.

Madras. Mr. A. W. Lushington¹ records the following girth measurements, presumably excluding bark, based on ring-countings in the Guntur taluk of the Kistna district :

Age (years) . . .	10	15	20	25	30	35
Girth (inches) . . .	7.1	13.9	19.4	24.9	34.1	43.2

The sapwood varied from three to six rings in thickness. He mentions elsewhere² that some samples gave an average of $1\frac{1}{2}$ rings per inch of radius : this rate of growth, equivalent to a mean annual girth increment of about $4\frac{1}{2}$ in., is extremely rapid. The soil is black cotton, and the normal rainfall is about 34 in.

2. *Acacia leucophloea*, Willd. Syn. *Mimosa leucophloea*, Roxb. White-barked acacia. Vern. *Reru*, *rinj*, *raunj*, *rhea*, *safed kikar*, Hind. ; *Hewar*, Mar. ; *Velvaylam*, Tam. ; *Tella tuma*, Tel. ; *Tanaung*, Burm. (Fig. 167.)

A moderate-sized to large thorny deciduous tree, with a somewhat spreading crown and a trunk often crooked and gnarled. Bark light yellowish grey to nearly white, smooth, exfoliating in irregular scales, light red inside ; bark of older trees rough and nearly black. Heartwood comparatively small, reddish brown streaked with darker and lighter colour, strong and hard. The wood, which is not of great value, is used for posts and beams, carts, wheels, agricultural implements and turning, also for fuel.

DISTRIBUTION AND HABITAT. This tree is found on the plains of the Punjab and United Provinces, particularly in the drier parts, in the Siwalik hills between the Jumna and the Ravi, Rajputana, central, western, and southern India, and Burma, chiefly in the dry zone. It is characteristic of dry regions, occurring chiefly in open scrub or thorn forests. In the Indian Peninsula it is often very common on trap and on black cotton soil, though it is also found on other geological formations. In the Deccan, the south Mahratta country, and the Central Provinces its associates vary from place to place, but include some or all of the following species : *Acacia Catechu*, *Zizyphus Jujuba*, *Z. Xylopyrus*, *Prosopis spicigera*, *Chloroxylon Swietenia*, *Soyimida febrifuga*, *Diospyros Melanoxylon*, *Aegle Marmelos*, *Butea frondosa*, *Anogeissus latifolia*, *Cassia Fistula*, *Azadirachta indica*, and other species, while in southern India in addition to most of these it is commonly associated with *Acacia Latronum*, *A. eburnea*, *Albizzia amara*, *Canthium parviflorum*, and *Dolichandrone crispa*.

In the dry zone of Burma it is one of the most characteristic trees, forming somewhat open forests, often on poor shallow soil, in association with *Acacia Catechu*, *Terminalia Oliveri*, *Tectona Hamiltoniana*, *Zizyphus Jujuba*, *Limonia acidissima*, and other dry zone species.

In its natural habitat the absolute maximum shade temperature varies from 105° to 120° F., the absolute minimum from 30° to 55° F., and the normal rainfall from 18 to 60 in.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The tree is leafless towards the end of the cold season and in the earlier part of the hot season, the new leaves appearing about April. The yellowish white flowers, in small globose

¹ Ind. Forester, xxi (1895), p. 255.

² Preliminary Working Scheme for the Guntur Babul Working Circle, Kistna District, 1893.

heads 0.25 in. in diameter, arranged in large terminal panicles, appear from August to November (sometimes May, according to Brandis); the tree is a conspicuous sight when in blossom. The pods, 4-8 in. long by 0.2-0.35 in. broad, flat, slightly curved, ripen from April to June (or earlier?). The pods are 10- to 20-seeded, and are scarcely dehiscent. The seeds (Fig. 166, *a*) are irregularly elliptical or rhomboidal, 0.2-0.25 in. by 0.15-0.2 in., dark brown, smooth, shining, compressed, with a hard testa: about 200 weigh 1 oz. The seed germinates readily with moisture and warmth, and does not require any special preparation.

GERMINATION (Fig. 166, *b-e*). Epigeous. The radicle emerges, the hypocotyl elongating with slight arching and carrying the cotyledons above ground; the testa usually remains partially enclosing the cotyledons until they expand, when it falls to the ground.

THE SEEDLING (Fig. 166).

Roots: primary root long, terete, tapering, wiry, white turning yellowish brown: lateral roots fairly numerous, fine, fibrous: nodules present. **Hypocotyl** distinct from root, 0.4-1.5 in. long, terete, tapering slightly upwards, expanded in a ring at the base, white turning green, glabrous. **Cotyledons**: petiole 0.1 in. long or less, glabrous: lamina 0.3-0.4 in. by 0.25-0.35 in., plano-convex, somewhat fleshy, ovate obovate or oblong, apex rounded, base broadly sagittate, entire, glabrous, bright green above, paler beneath. **Stem** erect, somewhat zigzag at the nodes, wiry, glabrous, green turning brown; internodes 0.3-1.2 in. long. **Leaves** alternate. Stipular spines 0.1-0.2 in. long. First leaf once paripinnate, rachis 0.5-0.7 in. long, terminating in a fine bristle, leaflets 4-8, usually six pairs, sub-sessile, 0.1-0.25 in. by 0.1 in. or less, obliquely oblong, entire, glabrous, mucronate; next six or more leaves bipinnate with one pair of pinnae and 5-15 leaflets on each pinna; subsequent leaves with two pairs, followed in the second season by leaves with three or four pairs of pinnae.

In loose fertile soil the growth of the seedling is fairly rapid, a height of 2 ft. or more being attained by the end of the first season. Under usual natural conditions in poor dry soil, however, the young plant grows slowly. A long taproot is developed early, and may reach a length of 1 ft. in the first month. Loose deep soil is very favourable to its development, and stiff clay is prejudicial. The seedling is sensitive to suppression by weeds: it is also very tender to frost, but has good power of recovery when killed back. Seedlings raised at Dehra Dun ceased growing by November-December, and new growth commenced in February-March.

SILVICULTURAL CHARACTERS. *Acacia leucophloea* is a decided light-demander. It stands drought well, and was not affected by the abnormal drought of 1899-1900 in the Indian Peninsula. Though young seedlings are sensitive to frost the tree itself is frost-hardy within its habitat: in the severe frost of 1910-11 in the Central Provinces it proved to be one of the hardiest of the indigenous trees. It suffers from browsing, goats in particular being very partial to it. It coppices well and produces root-suckers.

ARTIFICIAL REPRODUCTION. Experiments at Dehra Dun showed that direct sowing is more successful than transplanting. Young seedlings were found to transplant fairly well early in the first rainy season, but the transplanting checked their growth. Line sowings were found to be the most successful, as it is necessary to weed regularly, and this can be done most



FIG. 166. *Acacia leucophloea*. Seedling $\times \frac{1}{2}$.
a, seed ; *b-e*, germination stages ; *f-i*, development of seedling during first season.

effectively along lines. Sowings have given good results in Ajmer-Merwara in places where the soil was not too dry. Line sowings in conjunction with the raising of field crops have been tried experimentally in Berar, and this system would appear to be the most satisfactory one to adopt: the details of this form of sowing are given on p. 435, under *Acacia arabica*.

RATE OF GROWTH. Reliable statistics of rate of growth are wanting. The tree is generally considered to be slow growing. A section 2 ft. 5 in. in girth, including bark, in the silvicultural museum at Dehra Dun had 31 rings, giving a mean annual girth increment of 0.94 in.

3. *Acacia Catechu*, Willd. Cutch tree. Syn. *A. Sundra*, DC.; *Mimosa Catechu*, Linn. Vern. *Khair*, Hind., Mar.; *Kagli*, *shemi*, Kan.; *Karangalli*, Tam.; *Sundra*, *tella tumma*, Tel.; *Sha*, Burm.

A moderate-sized deciduous tree with a light feathery crown, the branchlets armed with twin hooked prickles. Bark 0.4–0.5 in. thick, dark grey or greyish brown, rough, exfoliating in long narrow strips, brown and red inside. Sapwood yellowish white; heartwood dark or light red, very hard and durable. The wood is largely used for house-posts, agricultural implements, wheels, tool-handles, and other purposes: it also gives excellent fuel and charcoal. The substances cutch and *kath* are obtained by boiling down chips of the heartwood: the former is largely exported for dyeing and tanning, and the latter is used for chewing with betel-nut. The tree sometimes reaches a fair size: Fig. 168 shows one 10 ft. 6 in. in girth. Prain¹ distinguishes three varieties:

(1) Var. *Catechu* proper. Calyx, petals, and rachis covered with spreading hairs. Chiefly in the Punjab, Garhwal and Kumaun, Bihar, Ganjam, and in the Irrawaddy valley: also in North Kanara and the Konkan (Talbot).

(2) Var. *catechuoides*. Calyx and petals glabrous, rachis puberulous. Chiefly in the Sikkim *tarai* and Assam, also in Upper Burma, Mysore, and the Nilgiris.

(3) Var. *Sundra*. Calyx, petals, and rachis all glabrous. Chiefly in the Indian Peninsula and Upper Burma.

DISTRIBUTION AND HABITAT. Throughout the greater part of India and Burma, except in the most humid regions. The tree is most typically found in one of two main classes of forest: (1) in the shingly or sandy alluvial beds of rivers and streams which may or may not be dry for a considerable portion of the year; here it is markedly gregarious, often forming entirely pure forests: (2) in dry types of forest on high land away from watercourses, where it is frequently more or less gregarious, though commonly mixed with other species characteristic of dry regions. Examples of forest types in different localities are given below, and it will be seen that although the tree is capable of growing on the poorest soil in dry localities, it occurs also in mixed forest of good quality—as in the drier types of teak forest in Burma—where it may attain considerable dimensions.

Rock and soil. *Acacia Catechu* occurs on a variety of geological formations and soils, though it undoubtedly thrives best on porous alluvium composed of sand and shingle and on well-drained sandstone, as in the Pegu Yoma. It is known to occur on granite, gneiss, schist, quartzite, shale, basalt, trap,

¹ Journ. As. Soc. Bengal, LXVI, ii (1898), p. 508.

limestone, conglomerate, and laterite, while as regards soil it is common on sandy and gravelly alluvium, and on loam or gravel with varying proportions of sand and clay ; it grows also on black cotton soil. It is frequent on arid shallow stony soil and grows even on sheet rock. In the poor shallow soils composed of *murram* or *kankar*, which are frequent in parts of the Indian Peninsula, it grows where few other species are able to survive ; this adaptability is seen also in parts of the sub-Himalayan tract, where it grows pure, though in stunted form, on poor hard soil composed largely of calcareous nodules, where hardly any other tree can exist. On stiff clay where the drainage is bad it becomes stunted and tends to die off early.

Climate. *Acacia Catechu* is essentially a tree of comparatively dry regions, though in its alluvial form it extends into regions of heavy rainfall, as in the eastern sub-Himalayan tract, where it is found in places where the rainfall is as much as 150 in. In gravelly riverain tracts, however, it has few competitors and is no doubt enabled to establish itself for that reason. Away from riverain tracts it occurs ordinarily in localities where the normal rainfall varies from 20 to 85 in. In its natural habitat the absolute maximum shade temperature varies from 105° to 120° F., and the absolute minimum from 30° to 55° F.

Local occurrence. *Sub-Himalayan tract.* *Acacia Catechu* is common throughout the sub-Himalayan tract from the Indus to Assam, ascending the Himalayan valleys to 3,000 ft. and sometimes to 4,000 ft. From the Jumna eastwards it occurs either gregariously in the beds of rivers and streams or in various types of dry mixed forest, where it may be either more or less gregarious or scattered. The riverain *khair* forests of northern India are very characteristic. They spring up on new alluvium along the banks or in the beds of the rivers and streams in the valleys of the outer Himalaya and the Siwalik range, on deposits of sand, shingle, and boulders, extending some distance out into the plains provided the alluvium remains sandy or shingly and does not reach the consistency of soft mud. In these alluvial forests the *khair* is either pure or mixed with *Dalbergia Sissoo*, and occasionally with *Acacia eburnea*, *Bombax malabaricum*, *Albizia procera*, and a few other species. It is also associated with characteristic grasses, the chief of which are *Saccharum Munja*, *S. spontaneum* (xerophilous form), *Aristida cyanantha*, *Triraphis mada-gascariensis*, and *Andropogon monticola*. There is often a dense undergrowth of *Adhatoda Vasica* in these riverain forests. The gregarious habit of the tree in this type of forest is shown in Fig. 169.

At the higher elevations it meets the hill species ; for example, above Ratighat in the Naini Tal hills, at 4,000 ft., it grows in a river-bed with *Quercus incana* and *Pinus longifolia* growing on the slopes down to the edge of the river : in the same locality it is found mixed with *Celtis australis* on old riverain boulder beds.

In non-riverain tracts the tree occurs either in scattered savannah lands or in various types of dry mixed forest, sometimes as a survival from former riverain forest which has become elevated at no very distant date above the river-bed owing to changes in the course of the river, but frequently on land, both flat and hilly, which shows no such recent transition, or on which it has sprung up naturally after the land has ceased to be new alluvium. In such



FIG. 167 *Acacia leucophloea*, Upper Burma.



FIG. 168 *Acacia Catechu* tree, 10 ft. 6 in. in girth, in
riverbank tract, Siwaliks, United Provinces.



FIG. 169. Ravine forest of *Leuca leucade* Sawahls, United Provinces. The tall grasses *Saccharum Manja*.

tracts the *khair* is frequently mixed with a variety of deciduous species, such as *Dalbergia Sissoo*, *Bombax malabaricum*, *Garuga pinnata*, *Odina Wodier*, *Ehretia laevis*, *Phyllanthus Emblica*, *Zizyphus Jujuba*, *Bauhinia racemosa*, *Holarrhena antidysenterica*, and others. On drier and poorer ground it is stunted, but survives under conditions which are unfavourable to the existence of almost every other species. Striking examples of its hardiness occur in certain parts of the submontane mixed forests of the Gonda district in the United Provinces, on undulating ground intersected by ravines; the soil, besides being very poor, is subject to erosion, which is hastened by grazing, and the roots of the trees are in consequence much exposed, as shown in Fig. 172. In the poorest parts of these tracts *Acacia Catechu* occurs pure, nothing else being capable of growing, but where the soil is somewhat more favourable it is associated with stunted specimens of *Diospyros tomentosa*, *Anogeissus latifolia*, *Buchanania latifolia*, and *Nyctanthes Arbor-tristis*. The soil, which is excessively poor, is a reddish clay with calcareous nodular pebbles.

West of the Jumna the riverain type of *khair* forest is scarce, being confined to a few localities, for example in parts of the Kangra valley, but the tree is common on the dry foot-hills, often associated with *A. modesta*, and extends in some places into the region of *Pinus longifolia*.

In the sub-Himalayan tract *Acacia Catechu* occurs in localities where the normal rainfall varies from 25 to 180 in.

Indian Peninsula. The tree is common throughout the greater part of the Indian Peninsula in dry types of mixed forest on a variety of geological formations and soils.

In the Central Provinces and elsewhere it occurs in open grass-lands, and in teak forest of a dry type as well as in forest devoid of teak, its commoner associates being *Terminalia tomentosa*, *T. Chebula*, *Lagerstroemia parviflora*, *Anogeissus latifolia*, *Diospyros Melanoxyton*, *Ougeinia dalbergioides*, *Buchanania latifolia*, *Zizyphus Jujuba*, *Z. Xylopyrus*, *Aegle Marmelos*, *Odina Wodier*, *Butea frondosa*, *Acacia leucophloea*, *Cochlospermum Gossypium*, *Holarrhena antidysenterica*, *Phyllanthus Emblica*, *Chloroxyton Swietenia*, *Soymida febrifuga*, *Cleistanthus collinus*, *Gardenia latifolia*, *G. lucida*, and other trees, as well as the bamboo *Dendrocalamus strictus*. On dry hills it is found with *Boswellia serrata* and *Sterculia urens*, in places where the soil is poor and shallow, with sheet rock cropping out. It is also found associated with *Hardwickia binata* on trap or on gravelly soil. In the Central Provinces it is one of the commonest species in a poor stunted type of forest where the soil has an excess of calcareous nodules on the surface, its chief associates here being *Chloroxyton Swietenia*, *Soymida febrifuga*, *Diospyros Melanoxyton*, *Buchanania latifolia*, and *Terminalia tomentosa*.

In Bombay it occurs in Guzerat, the Deccan, and the South Mahratta country in dry open thorn forests. It is associated with many of the species already named as well as with *Prosopis spicigera* and sometimes *Acacia arabica*; here also it forms poor stunted types of forest on dry calcareous or *murram* soil. Talbot says that it ascends to 3,700 ft. in the Khandesh Akran, and that it occurs nearly pure in larger or smaller patches on the low level laterite near the sea-coast in North Kanara and the Konkan. In the Dangs of Surat

it is common, but not so plentiful as it once was, having been heavily worked at one time for catechu boiling.

In Chota Nagpur it is found not only in dry mixed deciduous forest but also frequently in association with sal. It occurs in the dry forests of Central India and Rajputana, often growing on mere sheet rock in the hilly tracts. It is common in Merwara associated with *Anogeissus pendula*, *Albizzia odoratissima*, *Boswellia serrata*, *Acacia leucophloea*, and other species.

In Madras it is common in dry mixed forests, often on dry stony soil, associated with *Acacia leucophloea*, *Albizzia amara*, *A. odoratissima*, *Chloroxylon Swietenia*, *Prosopis spicigera*, *Cassia Fistula*, *Anogeissus latifolia*, *Zizyphus Jujuba*, *Z. Xylopyrus*, *Santalum album*, *Hardwickia binata*, and others.

Burma. *Acacia Catechu* is one of the commonest trees in the dry zone of Upper Burma, where it occurs partly in the form of pure crops in the sandy beds of streams and partly on dry ground away from rivers and streams. The riverain cutch attains fairly large dimensions, but the trees on the higher ground are often stunted, forming scrub forests in association with *Acacia leucophloea*, *Terminalia Oliveri*, *T. tomentosa*, *Tectona Hamiltoniana*, *Capparis burmanica*, *C. flavicans*, *Cassia renigera*, *Bauhinia racemosa*, *Zizyphus Jujuba*, *Azadirachta indica*, *Diospyros burmanica*, *Limonia acidissima*, *Flacourtia cataphracta*, *Gardenia turgida*, *Phyllanthus Emblica*, *Pentacme suavis*, and occasionally *Dipterocarpus tuberculatus*. In this dry region, where the rainfall varies from about 23 to 40 in. and the soil is often poor and shallow, the trees are for the most part of small size and the crop is open. Cutch trees were formerly more plentiful than they are now, but have been extensively cut out for cutch boiling, not only the stems but also the stumps and main roots having been utilized for this purpose.

In Burma the tree extends well outside the dry zone proper, occurring both in Upper and in Lower Burma and in the Shan States in mixed deciduous forests with or without teak, in association with *Terminalia tomentosa*, *T. Chebula*, *Xylia dolabriiformis*, *Homalium tomentosum*, *Pterocarpus macrocarpus*, *Dalbergia cultrata*, *Pentacme suavis*, *Shorea obtusa*, and many other species characteristic of the drier types of the upper mixed forest. Bamboos are also common, the chief being *Dendrocalamus strictus*, *Bambusa Tulda*, and *Cephalostachyum pergracile*. In the Pegu Yoma the tree extends southward to the northern part of the Tharrawaddy district, where on the well-drained sandstones and shales of this range it attains large dimensions, the minimum felling diameter under the Taungnyo working plan being fixed at 1 ft. 6 in. In the Thayetmyo forest division (East Yoma and other reserves) the exploitable girth is fixed at 4½ ft. In Burma it does not extend into regions with a rainfall higher than 65 in.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The tree is leafless for a time during the hot season. In northern India the leaves are shed about February, the new leaves appearing towards the end of April or during May. When leafless the *khair* forests have a grey and dreary appearance, in strong contrast to the fresh green of the sissoo crops, which by that time have come into new leaf. By June, however, the *khair* forests have acquired their new delicate green feathery foliage, and are a beautiful sight. The whitish flowering spikes, 2-3.5 in. long, which are axillary on the young shoots, appear with the new



FIG. 170. *Acacia Catechu*—SEEDLING $\times \frac{1}{2}$

a—Fruit b—Seed

c - g—Germination stages h - j -Early development of seedling, first season
k - Seedling towards end of second season

leaves, and add to the beauty of the trees. The trees continue in flower until July or August, sometimes later. The pods develop rapidly, becoming full-sized by September or October, and turning from green to reddish green and then to brown: they begin to ripen by the end of November and continue ripening during December and early January. The pods (Fig. 170, *a*) are 2–4 in. long by 0.4–0.6 in. broad, straight, flat, dark brown, shining, dehiscent, usually three- to six-seeded. The seeds (Fig. 170, *b*) are 0.25–0.35 in. by 0.2–0.3 in., broadly ovate or orbicular, dark greenish brown, smooth, shining, moderately hard, with a hard testa which becomes soft and pliant on soaking. About 900–1,100 seeds weigh 1 oz.

The pods dehisce not long after ripening, and commence falling in January, continuing to fall in the succeeding months: the seeds adhere to the pod valves, and the latter being light are often blown to a considerable distance from the trees, dissemination of the seed being effected in this way. In alluvial tracts the dissemination of the seed is further effected by water. Some pods remain on the tree until the following October, by which time, however, the seed has become so damaged by insects as to be useless.

As a rule the tree seeds well every year. The seed can best be collected by stripping the pods off the trees in December or early January and spreading them in the sun for a few days. The seeds cling tenaciously to the pod valves, and in order to detach them it is necessary to heap the pods on a large cloth and beat them well with sticks, after which the seeds can be separated by shaking and winnowing in a flat basket.

The seed is badly subject to insect attacks, even when carefully stored. Seed kept for one year was tested at Dehra Dun and found to be quite unfertile: it is not certain how far this was due to insect attacks. It is advisable, therefore, to sow the seed the year in which it is collected. The fertility of fresh undamaged seed is high. The seed germinates readily with moderate rain, and requires no special preparation to stimulate germination.

GERMINATION (Fig. 170, *c-g*). Epigeous. The radicle emerges first and curves downwards; the hypocotyl then elongates, with or without arching, and raises above ground the cotyledons enveloped by the testa. The cotyledons expand, turning from yellow to pale green, and the testa falls to the ground.

THE SEEDLING (Fig. 170).

Roots: primary root long, wiry, thickening considerably after a few months, terete, tapering, whitish or pale brown becoming darker brown: lateral roots few to numerous, short, fibrous or wiry, distributed down main root: nodules present. **Hypocotyl** distinct from root, 0.5–0.8 in. long, terete, expanded in a ring at the base, white becoming green, glabrous or sparsely pubescent in upper part. **Cotyledons** very shortly petiolate, plano-convex, somewhat fleshy, 0.3–0.4 in. in diameter, orbicular, entire, base sagittate, glabrous, yellow becoming green, obscurely 3-veined. **Stem** erect, somewhat zigzag at the nodes, thin, delicate at first, becoming wiry, green or reddish, young parts pubescent, elsewhere glabrous or nearly so. **Leaves** alternate. Stipules minute, subulate, caducous. First leaf once paripinnate with three to four pairs of opposite leaflets 0.2–0.25 in. by 0.1 in., rachis pubescent; subsequent leaves bipinnate, at first with one pair, then with two pairs of pinnae, each pinna at first with 3–5 pairs of leaflets, the number increasing with succeeding leaves, leaflets 0.2–0.4 in. by 0.1–0.2 in.; the number of pinnae increases in subsequent leaves.

Under favourable conditions the growth of the seedling is rapid from the commencement, plants regularly weeded and watered attaining a height of 3 ft. or more in three months from germination. Branching takes place at an early age, and the general habit is more or less straggling. The seedling develops a long taproot, which may attain a length of 2 ft. or more in three months.

Under natural conditions the growth of the seedlings may be extremely slow, particularly if they are hampered by weeds or subject to damage by grazing. Thus a plot of natural seedlings 200 sq. ft. in area on sand and shingle among scattered tufts of grass about 3 ft. high in a dry river-bed in the Siwaliks was kept under observation for about $4\frac{1}{2}$ years: the following shows the number of seedlings counted and their maximum height at different stages:

Date of observation.	No. of seedlings present.	Maximum height of seedlings.	
		ft.	in.
December 11, 1910 (end of 1st season) . . .	201	0	6
December 28, 1911 (end of 2nd season) . . .	—	1	0
December 19, 1913 (end of 4th season) . . .	74	0	11
April 14, 1915 (beginning of 6th season) . . .	24	0	10

These results show a steady diminution in the number of seedlings and no progress in their growth, this being due mainly to damage by grazing; nearly all the survivors were found in the clumps of grass, where they received a certain amount of protection.

The beneficial results of irrigation and weeding, of which the latter is of even more importance than the former, are well demonstrated by the following figures showing the development of seedlings in various experimental plots at Dehra Dun:

Acacia Catechu: development of seedlings under varying treatment.

Time of observation.	Irrigated.		Unirrigated.			
	Regularly weeded.	Not weeded.	Regularly weeded.		Not weeded.	
				ft. in.		ft.
End of 1st season	Maximum height 5 ft. 2 in. (very vigorous)	Maximum height 5 in. (weakly)	(1) Maximum height (fairly vigorous)	0 8	(1) Maximum height (very weakly)	0
			(2) " "	3 8	(2) " "	0
			(3) " "	2 3	(3) " "	0 6
End of 2nd season	Maximum height 10 ft. 3 in. (very vigorous)	Maximum height 1 ft. 0 in.	(1)	4 0	(1)	0 7
			(2)	6 3	(2)	1 5
			(3)	12 9	(3)	1 10
			(4)	12 0	(4)	1 2
			(5) " "	10 0	(5)	2 3
End of 3rd season	Maximum height 14 ft. 0 in. (very vigorous)	Maximum height 1 ft. 1 in.	(1) " "	9 6	(1) Height 2 ft. 6 in. to 7 ft. : thin lanky stems among growth of weeds	
			(2) Maximum height	18 8		
			Mean height	8 4		
			Maximum girth	0 7		
			(3) Maximum height	14 10		
			(4) Maximum height	17 9		
			Mean height	6 0		
			Maximum girth	0 $7\frac{1}{2}$		

In most of the unweeded plots the seedlings were all killed out by suppression or had damped off before the end of the third season. One of the commonest forms of mortality in the case of seedlings in a heavy growth of weeds is the

damping off to which they are subject during the rains : in tall open grass, however, where they are not subjected to such a degree of damp, they are capable of making their way up successfully, though their development is comparatively slow during the process.

The effect of light on the development of the seedling has been studied at Dehra Dun in the case of plants grown in plots under varying degrees of shade : these tests proved the seedlings to be strongly light-demanding, and liable to be killed out in one season where the shade is at all dense. The seedlings are frost-tender during the first few years, and are also apt to suffer from drought during long periods of dry weather. In dry regions they sometimes die back for a few years in succession, eventually shooting up after the root has established itself. Rats do much injury to the seedlings by gnawing through the taproots. The power of recovery of the plants, however, is good, numerous cases having been observed of new shoots being sent up from the portions of the taproots left in the ground after this form of damage. Similar new shoots were found to be sent up from the roots in the case of plants thinned out in unirrigated line sowings at Dehra Dun, in which the taproots were severed a few inches below ground-level. Young plants are very subject to browsing by deer.

SILVICULTURAL CHARACTERS. *Acacia Catechu* is a strong light-demander. Within its habitat it is decidedly frost-hardy, though young seedlings are somewhat tender : in the abnormal frost of 1905 in northern India it stood the frost better than most species, though young coppice growth was killed back. It is often found thriving in frosty grass-lands where tender species succumb. Although decidedly xerophilous in character, and capable of growing in dry situations where almost every other species fails to survive, it may suffer severely in years of abnormal drought, as in 1899–1900 and subsequently in the Indian Peninsula, and in 1914–15 in Palamau, Chota Nagpur. In the abnormal drought of 1907 and 1908 in Oudh it was unaffected on the low alluvial lands where it grows.

The tree coppices well up to a moderate size and produces root-suckers, particularly where the roots have been exposed : coppice-shoots, however, require complete light for their development, and under shade they are frequently not produced at all, the stools dying off. It is very subject to damage by browsing, and responds readily to closure to grazing. Porcupines are particularly destructive to the trees, gnawing the bark off round their bases and often killing them. Ranger Basti Ram¹ reports that he has found a smearing of lime efficacious in keeping them off. An American plan for dealing with porcupines is to soak small boards in brine and strychnine and nail them to the bases of the trees ; the porcupines have a partiality for salt and gnaw the boards, dying of strychnine poisoning.

In the mixed forests *Acacia Catechu* is subject to the usual damage from climbers. In the sub-Himalayan alluvial forests a very characteristic climber is *Dregea volubilis*, which does great damage ; other common climbers in these forests are *Cryptolepis Buchanani* and *Vallaris Heynei*.

NATURAL REPRODUCTION. Under natural conditions the seed is disseminated by wind, the seeds adhering to the light pod-valves ; in alluvial

¹ Ind. Forester, xli (1915), p. 383.

tracts water is also an important agency. Germination takes place early in the rainy season, and the early development of the seedling is greatly favoured on loose soil free from weeds. Thus on alluvial sand or gravel countless numbers of small seedlings may be found in the early part of the rainy season, not only in the open, but also under comparatively dense cover. In the latter case they die rapidly owing mainly to shade and to damping off, and by the end of the season hardly a seedling is to be found. In the open a fair proportion survive provided they are protected from grazing: frequently, however, there is high mortality from drought, particularly if the soil is stiff or shallow and the roots have difficulty in penetrating it. The seed germinates readily with heavy rain, and although germination takes place ordinarily at the commencement of the monsoon it may begin earlier in the season if abnormal falls of rain occur; when this happens the seedlings almost invariably die off or the germinating seed perishes in the ensuing spell of dry weather. Such mortality is particularly marked in the case of seeds germinating on the surface of the ground. Experiments at Dehra Dun showed that this early germination takes place more readily on ground exposed to the sun than in shady places, owing to the greater warmth in the former case. In alluvial riverain situations the tufts of grass which frequently appear on new ground, provided they are not too dense, act as a useful protection from drought in the early stages. In wet and sodden grass, however, the seedlings damp off.

The adverse effects of grazing have been alluded to above, under 'the seedling', in the case of a riverain plot in the Siwaliks. A striking example of the benefits of closure to grazing came under my notice in the submontane mixed forests of the Gonda district, United Provinces, along a central fireline which separated a block of forest permanently closed to grazing from an adjoining block open to grazing. The forest on either side of the line was similar, except that on the side closed to grazing *khair* trees of all sizes filled up every gap, while on the side open to grazing this species was represented by only a few old trees. In one part the grazed forest consisted of a rather open growth of nearly pure *bael* (*Aegle Marmelos*), while on the opposite side of the line the forest closed to grazing consisted of a dense crop of *khair* with *bael* trees scattered through it. Numerous other instances might be quoted of the adverse effects of grazing on the natural reproduction of *Acacia Catechu*, but the above will suffice.

Forest Ranger A. K. Desai¹ remarks on the large quantity of *khair* reproduction which appeared in gaps formed by the heavy exploitation of trees killed by the abnormal drought of 1899-1900 in the Godhra range of the Panch Mahals, Bombay, this reproduction being stimulated by the admission of light and warmth, and no doubt also by the breaking up of the soil during the extraction of the timber.

The freedom with which natural reproduction springs up in alluvial riverain tracts is remarkable. The chief factors favouring it in such localities are the new loose soil free from heavy weeds and the abundance of light, while the soil moisture obtained by percolation no doubt also assists the development of the seedlings. As the crops become older and elevated above the river-bed through changes in the course of the river, the conditions for natural repro-

¹ Ind. Forester, xxxiv (1908), p. 15.

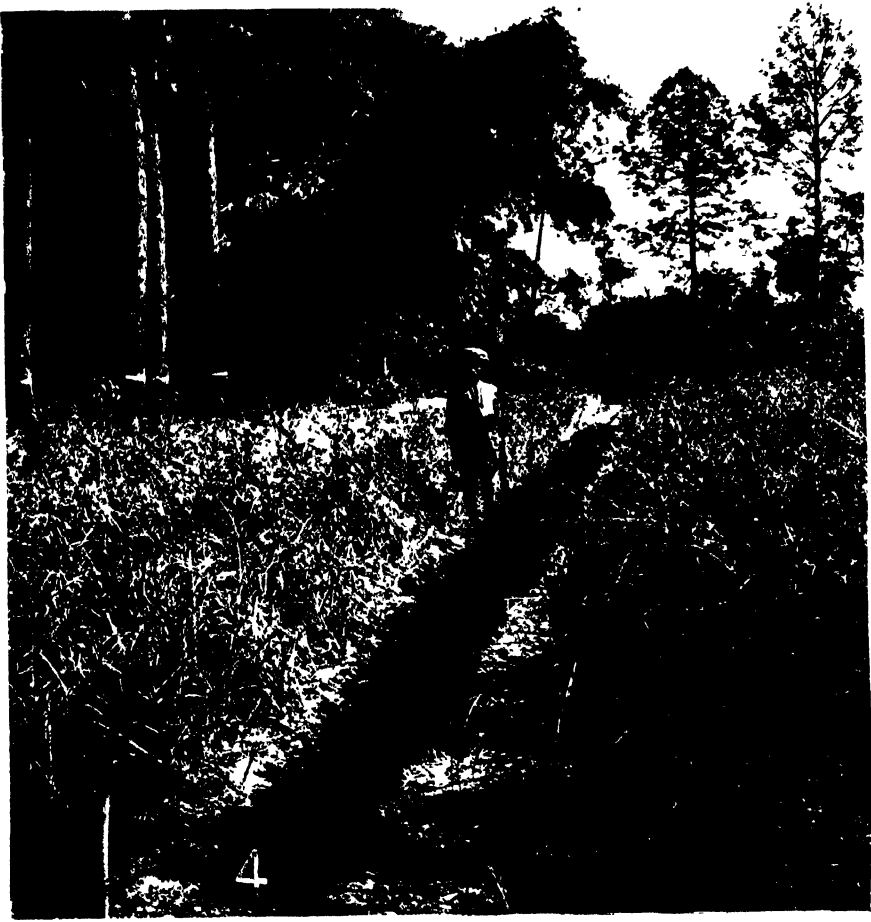


FIG. 171. Line sowings of *Acacia Catechu* 3½ months old in conjunction with field crops, Dehra Dun.



FIG. 172. *Acacia Catechu* on very poor eroded ground, Gonda district, United Provinces

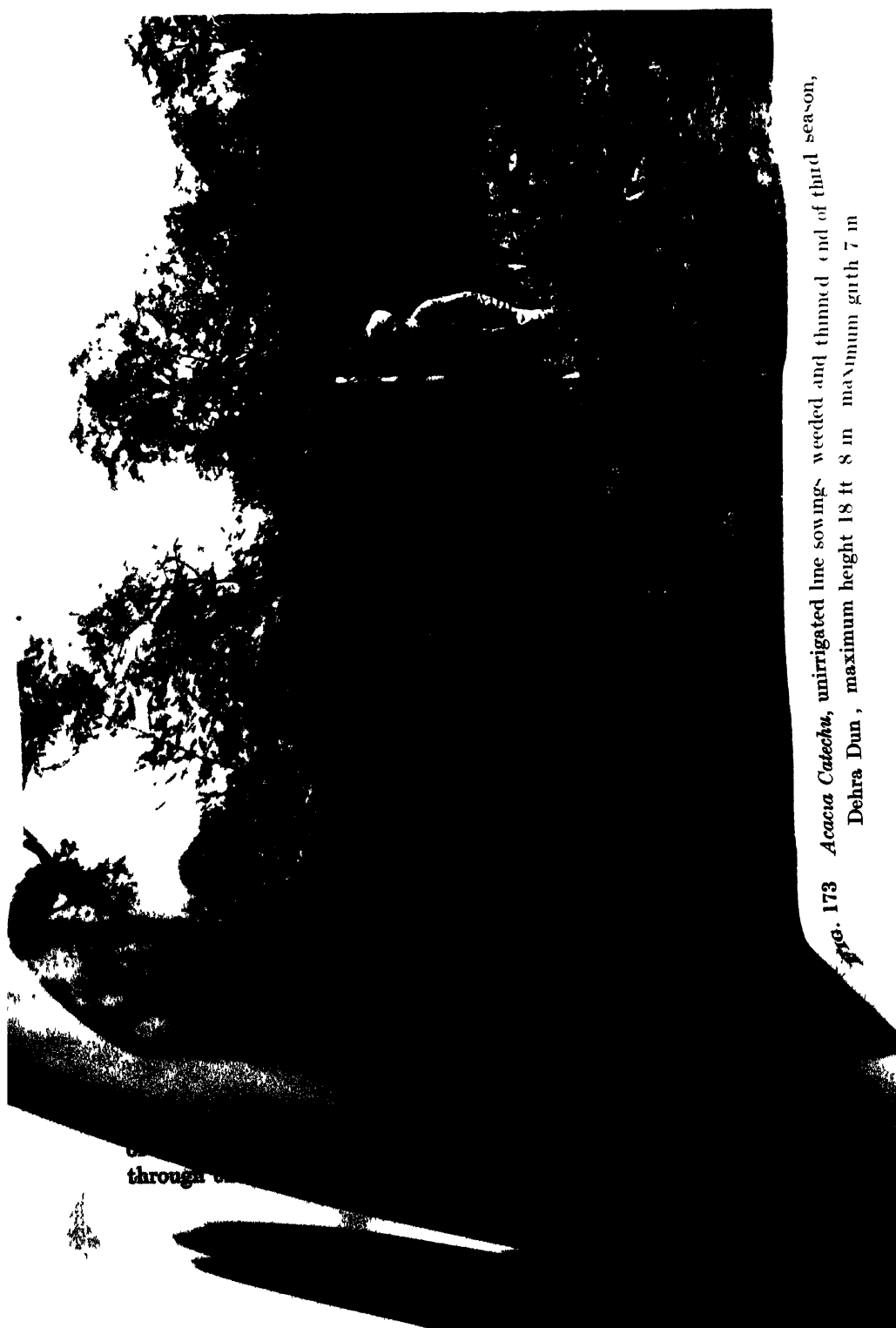


fig. 173 *Acacia Catechu*, unirrigated line sowings weeded and thinned end of third season,
Dehra Dun , maximum height 18 ft 8 in maximum girth 7 in

duction change. The ground becomes harder and a dense undergrowth of *Adhatoda Vasica* or other plants frequently makes its appearance. Under such conditions natural reproduction is no longer possible, and although it continues to take place where new alluvium is thrown up it ceases under the old crops.

ARTIFICIAL REPRODUCTION. Numerous experiments in the artificial reproduction of *Acacia Catechu* have been carried out at Dehra Dun. These have shown that transplanting cannot be relied on, but that direct sowing, if carried out properly, is highly successful. Transplanting was tried under different conditions, both in the first and in the second season, and moderate success was attained only by transplanting young plants early in the first rainy season, care being taken to avoid any injury to the root-system. This, however, does not appear to be the experience everywhere, for Mr. Pearson ¹ says regarding this species in Bombay. 'The only results at all favourable with *khair* are those when carried out with large plants.' In the Dehra Dun experiments pruning of the roots and stem invariably resulted in the death of the seedling.

The success of direct sowings depends on: (1) the degree to which the soil is kept loose for the first two years or so after sowing; (2) thorough weeding; (3) abundance of light from the commencement. In addition the thinning out of the young plants has a marked effect on their development. Irrigation undoubtedly stimulates the growth of the plants, but is not essential provided regular loosening of the soil is carried out.

In the Dehra Dun experiments the greatest success was attained by line sowings, particularly in combination with the raising of field crops. A distance of 8 to 10 ft. between the lines should be sufficient. It was found necessary to sow the *khair* seed along the lines in clear strips 2 to 3 ft. wide, the field crops being sown in the intervening spaces (see Fig. 171). Where the crops were sown continuously over the area many of the seedlings were killed by suppression, the development of the survivors was poor and the stocking was incomplete, while the sudden exposure when the crops were reaped caused the leaves of the seedlings to fall prematurely and many of the seedlings to die down partially. The field crop employed was the lesser millet or *mandwa* (*Eleusine coracana*), which was sown in May or June and reaped in October: the land was cleared forest land, and the millet crop was dense and heavy and up to 3½ ft. in height. The *khair* seed was sown at the same time as the millet, and the lines were kept weeded both when the crops were on the ground and after they were reaped. The results along the weeded lines were admirable, the seedlings being plentiful and vigorous and attaining a maximum height of 2 ft. 3 in. by the end of the first season and 6 ft. 3 in., with an average of 4 ft. 3 in., by the end of the second season. Regular thinning of plants, com-

sowing, and regular weeding, thinning, and loosening of the soil were carried out subsequently : 1 lb. of seed was found sufficient for about 350 ft. length of line. Fig. 173 shows line sowings at the end of the third season.

Sowings of *Acacia Catechu* have been carried out in many parts of India and Burma in a variety of ways. In the grassy savannahs of Oudh line sowings have proved successful in spite of a fairly tall growth of grass in the rains. In Berar line sowings in conjunction with field crops have also done well : the system employed has been described under *Acacia arabica* (p. 435).

Mound and ridge sowings have been carried out with varying success. Owing to their high cost, however, they are hardly justified except on very stiff soil where the drainage is bad. Broadcast sowing has also been frequently tried, often with success : where suppression from weeds is to be feared, however, it cannot compare with line sowings.

In Burma numerous cutch plantations have been formed on the *taungya* system, the seed being dibbled 6 ft. by 6 ft. or 12 ft. by 3 ft. or 9 ft. by 4 ft. on temporary forest clearings in which field crops, usually hill rice, are raised. In many cases mixed plantations of teak and cutch have been formed in this way. The two species, however, do not mix well, their requirements being dissimilar ; not only does the cutch damage the teak by contact with it, but one of the species in time usually ousts the other, the cutch or the teak gaining the upper hand according to the nature of the locality. These mixed plantations are not as a rule formed now. A description of these *taungya* plantations is given under *Tectona grandis*.

SILVICULTURAL TREATMENT. Under existing working plans the tree is frequently worked under coppice or coppice-with-standards, both in alluvial tracts and in mixed forests. The *khair* and *sissoo* forests of the Ganges islands, for example, are worked as simple coppice on a rotation of twenty years, a protective belt at least 100 ft. wide being left uncut round the edges of the islands. Provided the trees coppiced are not too old, and provided the standards are not numerous enough to suppress the coppice, this system has usually answered satisfactorily for the production of poles.

The treatment under high forest is a more difficult matter. Several working plans, both in India and in Burma, prescribe selection fellings, the object of which is to remove mature trees. This, however, does not ensure reproduction, which cannot be obtained under any system which does not involve removal of the overwood and of weed-growth. This being so, as far as experience goes the only system under which complete regeneration can be ensured on a given area appears to be that of clear felling with artificial reproduction. The question of regenerating riverain crops of *Dalbergia Sissoo* has been discussed in some detail on p. 314. The system proposed is to divide these crops into two classes, stable and unstable, the former to be regenerated artificially, while in the latter the fellings would consist of utilizing marketable material, regeneration being left to the vagaries of the river. For riverain crops of *Acacia Catechu* exactly the same procedure is indicated.

In crops of *Acacia Catechu* which tend to become very dense, regular thinnings are of great importance.

RATE OF GROWTH. *Coppice.* Statistics relating to coppice growth are

scanty. Measurements in Bhandara, Central Provinces, in 1912-13 showed the average height of coppice-shoots one year old to be 6 ft. 4 in. as against 7 ft. 1 in. for teak and 6 ft. 6 in. for *Terminalia tomentosa*. Measurements recorded by Mr. A. F. Broun at Bullawala near Dehra Dun in 1886 showed an average girth of 8 in. and an average height of 11 ft. 4 in. for coppice nine years old.

High forest. The annual rings are usually, but not always, quite distinct, and the rate of growth can thus as a rule be deduced from ring-countings. Measurements show the growth to be extremely variable. Gamble says Himalayan specimens show 5 rings per inch of radius, giving a mean annual girth increment of 1.26 in. ; a specimen from the bed of the Mahanadi, Darjeeling *tarai*, showed 3.8 rings per inch of radius, giving a mean annual girth increment of about 1.7 in., which is fast.

Extremely slow growth is shown in an unthinned riverain sample plot of *khair* mixed with *Dalbergia Sissoo* in the Saharanpur Siwaliks in a somewhat dry locality with a soil of sand and boulders. The measurements, which applied to forty-five trees and extended over five years only (1910-11 to 1915-16), gave the following results :

Acacia Catechu : girth increment in unthinned sample plots, Siwaliks,
United Provinces.

years.	Mean girth.		Age. years.	Mean girth.	
	ft.	in.		ft.	in.
10	0	0½	70	1	5½
20	0	2	80	1	10
30	0	4½	90	2	2¼
40	0	7	100	2	6½
50	0	9½	110	2	10
60	1	1½			

Although these results can hardly be regarded as very accurate owing to the short period over which the measurements extended and to the fact that dominated and suppressed trees were included, they emphasize the importance of carrying out regular thinnings to promote more rapid growth. A somewhat faster rate of growth is shown in an unthinned sample plot in the Sathiana block of the North Kheri forests. Measurements, which extended over eight years and related to seventy-five trees, gave the following results :

Acacia Catechu : girth increment in unthinned sample plot, Sathiana block,
North Kheri, United Provinces.

Age. years.	Mean girth.		Age. years.	Mean girth.	
	ft.	in.		ft.	in.
20	0	8	90	4	0
30	1	2½	100	4	5
40	1	8½	110	4	10
50	2	2	120	5	2½
60	2	7½	130	5	7
70	3	1	140	5	11
80	3	6½			

This plot was situated within the limits of the sal forests, not on recent alluvium.

Measurements of 100 trees by Mr. Beadon Bryant in the Kumaun sub-Himalayan tract gave the following results : ¹

Girth.	Average age. years.	Average volume. cub. ft. solid.
Over 4 ft. 6 in.	53	35.0
3 ft.-4 ft. 6 in.	36	16.5
1 ft. 6 in.-3 ft.	20	4.0
1 ft.-1 ft. 6 in.	15	1.3

Periodical measurements of 117 trees in three unthinned sample plots in the Palamau district of Bihar and Orissa gave the following results : ²

Acacia Catechu : girth increment in unthinned sample plots, Palamau, Bihar and Orissa.

Age. years.	Mean girth. ft. in.	Age. years.	Mean girth. ft. in.
30	0 4	90	1 10½
40	0 7½	100	2 2
50	0 10	110	2 7
60	1 0	120	3 0
70	1 3	130	3 7
80	1 7		

Mr. W. R. Fisher ³ records very rapid growth in a plantation at Kuch Behar where the seed was sown in 1873 and 1874 : measurements made in 1881, the plantation being then seven to eight years old, showed an average and maximum girth of 1 ft. 6 in. and 2 ft. 1 in. respectively.

Measurements recorded by Mr. J. Nisbet ⁴ from the dry, intermediate, and moist zones in Upper Burma showed rapid growth, particularly in the moist zone. The following is a summary :

Acacia Catechu : girth measurements, Upper Burma.

District.	Character of forest.	Number of measure- ments.	Mean annual girth increment. in.
Yamethin and Meiktila	Dry zone : dry open forest and scrub jungle	8	2.2
Yamethin and Meiktila	Intermediate zone : mixed forest and scrub jungle	3	2.2
Yamethin (Pynmana sub-division) and Minbu	Moist zone : mixed and savannah forest	10	3.54

Ring-countings which I carried out in 1902 in the Meiktila district of Upper Burma on twenty stumps in pure riverain catch forest on sandy soil gave the following results :

Acacia Catechu : girth increment, riverain forest, Meiktila district, Upper Burma.

Age. years.	Girth including bark. ft. in.	Mean annual girth increment. in.
5	0 6	1.2
10	1 8	2.0
15	3 0	2.4
17	3 6	2.47

¹ Working Plan for the Kumaun Forest Division, 1893.

² Ind. For. Records, vol. vi, pt. v.

³ Ind. Forester, vii (1881), p. 41.

⁴ *Ibid.*, xix (1893), p. 11.

This shows rapid growth, and as the rings were perfectly distinct the figures may be regarded as accurate. The diameter of heartwood averaged 0.67 of the whole diameter including bark.

Proportion of heartwood. The following measurements by Mr. A. Rodger of about 100 sections of cutch trees in the Thayetmyo and Prome districts of Burma show that the percentage of heartwood increases with size :

Acacia Catechu : measurements of heartwood in trees of different sizes.

Diameter including bark.	Corresponding girth.	Diameter of heartwood.	Percentage of total area of section occupied by heartwood.
in.	ft. in.	in.	
6	1 7	3.6	35
7	1 10	4.7	45
8	2 1	5.6	49
9	2 4	7.0	61
10	2 7	8.0	64
11	2 11	9.0	67
12	3 2	9.0	56
13	3 5	10.3	65
14	3 8	10.7	59
15	3 11	12.5	64
16	4 2	12.5	61
17	4 5	13.6	63
18	4 9	15.2	68
19	5 0	16.0	70
20	5 3	17.0	73
21	5 7	18.2	75
22	5 9	18.7	72
24	6 3	21.2	80

4. *Acacia modesta*, Wall. Syn. *Mimosa dumosa*, Roxb. Vern. *Phulai*, Punjab.

A moderate-sized thorny tree with a bushy rounded crown and drooping branchlets. Bark rough, with numerous irregular cracks. Sapwood large, white : heartwood very hard, dark brown with black streaks, not durable, used for cane-crushers, Persian wheels, and agricultural implements, and largely for fuel. The tree is useful for afforestation purposes on poor stony soil in the dry lower hills and plains : it also makes a good hedge plant if trimmed.

This tree occurs more or less gregariously in the dry outer hills and valleys of the Suliman Range, ascending to 4,000 ft. in the Salt Range, the sub-Himalayan tract from the Jumna westwards, ascending to 4,000 ft., the northern part of the Punjab plains, and Baluchistan. In Hazara it is common on limestone in the scrub forests of Khanpur, and occurs in the Kagan valley on hot shaly hill-sides up to 5,500 ft. Within its natural habitat the rainfall varies from 15 to 50 in., the absolute maximum shade temperature may rise to over 120° F., and the absolute minimum may sink to well under freezing-point.

It is found on various geological formations, including limestone, sandstone, conglomerate, and shale, and is capable of growing in poor dry shallow soil where few other species can survive. It may occur pure or in mixture with other trees. Among its commoner associates are *Olea cuspidata*, *Acacia Catechu*, *Flacourtia Ramontchi*, *Tecoma undulata*, *Prosopis spicigera*, *Bauhinia variegata*, *Odina Wodier*, *Zizyphus Jujuba*, *Ehretia laevis*, and other miscel-

laneous species, often with an undergrowth of *Dodonaea viscosa*, *Carissa spinarum*, *Adhatoda Vasica*, *Woodfordia floribunda*, and other shrubs. It extends into the lower limits of *Pinus longifolia* in some parts of the outer Punjab hills. On poor dry localities at low elevations it is sometimes associated with *Salvadora oleoides* and *Capparis aphylla*. The new leaves appear in March: they are of a delicate green colour, but turn later to an ashy grey. The spikes of fragrant white flowers appear from March to May, when the trees are conspicuous with their masses of white tasselled blossoms. The pods ripen in the autumn and hang long on the tree; they are 2-3 in. long by 0.5 in. broad, flat, indehiscent, three- to five-seeded. The seeds, like those of *A. arabica*, are subject to the attacks of weevils. The tree seeds freely at frequent intervals, but occasional bad seed-years occur.

The tree is a drought-resistant species. It coppices well, and is usually worked as coppice-with-standards. The coppice-shoots as well as seedling plants require protection from browsing, as they suffer much damage from goats, sheep, and camels. Seedling reproduction is somewhat disappointing, and in many localities grazing is largely the cause of this. The tree has been raised artificially by direct sowings in afforestation operations in the outer hills.

An attempt was made by Mr. A. M. Reuther during the preparation of the Kalachitta working plan¹ to deduce the rate of growth by ring-countings on stumps of trees selected and felled for the purpose. As the rings are not always easy to distinguish he was unable to place absolute reliance on the results, which must be taken as approximate only. From the recorded measurements the following statement showing the approximate rate of growth has been prepared:

Acacia modesta: rate of growth in Kalachitta forest.

Age. years.	Mean height. ft.	Mean girth. ft. in.
10	6.0	0 5.7
20	12.0	0 11.4
30	15.0	1 5.0
40	17.5	1 10.8
50	19.7	2 4.6

Parker says the growth is very slow, plantations made in the sub-Himalayan tract having reached a height of 18-20 ft. in as many years, though the girth was only about 1 ft. at the base.

5. *Acacia Senegal*, Willd. Syn. *A. rupestris*, Stocks. Vern. *Khor*, Sind; *Kumta*, Rajputana.

A small thorny deciduous tree, usually gnarled, ordinarily reaching a height of 10-15 ft. and a girth of 1-2 ft. Bark smooth, pale greenish grey, peeling off in flakes and exposing the yellowish new bark underneath; branches smooth, grey, shining, flexuose. The wood, which is hard with a nearly black heartwood, is used for weavers' shuttles and for fuel, and the true gum-arabic of commerce is obtained from wounds in the bark. In habit and appearance the tree resembles *A. modesta*, but is readily distinguished by its smooth pale bark, its infra-stipular spines in threes, and its larger pods.

This is a tree of the arid regions of India, occurring on the dry rocky hills of Sind, the south-east Punjab, the Aravalli, and the other hills of Raj-

¹ Working Plan for the Kalachitta Forest, Rawalpindi Forest Division, 1897.

putana, where it is abundant, and Ajmer ; it is also found in Arabia and Africa. In its Indian region the absolute maximum shade temperature may rise to over 120° F., and the absolute minimum may sink to well under freezing-point, while the normal rainfall varies from about 10 to 25 in. The tree occurs on the poorest soil on rocky hills and sandy tracts. In Ajmer it is associated with *Anogeissus pendula*, *Acacia Catechu*, and *Boswellia serrata* : here it produces abundant seed every year, and is said to regenerate freely under conditions adverse enough to prevent the regeneration of *A. Catechu*. Parker says it regenerates much more freely than *A. modesta*, and that it has been employed successfully for afforesting bare rocky hills and shifting sand in the Jaipur state, Rajputana. Mr. E. McArthur Moir,¹ writing of sowings of this and other species in the dry regions of Ajmer-Merwara, notes that the seedlings died back for two or three years before finally establishing themselves and becoming capable of resisting drought and frost, developing in the meantime taproots of great length and thickness. The tree is readily browsed by camels and goats. It is a hardy species, surviving under most adverse conditions.

The fragrant white flowers, in lax spikes 2–4 in. long, appear from August to December ; the pods, which ripen the following spring, are 3 in. long by 0·7 in. broad, thin, flexible, brown when ripe, five- or six-seeded, tardily dehiscent.

6. *Acacia planifrons*, W. and A. Umbrella thorn. Vern. *Kodaivelam*, *odai* (which is also a name given to *A. Latronum*), Tam. ; *Godugu thumma*, Tel.

A small to moderate-sized tree with a flat spreading dense umbrella-like crown, common and often gregarious in the southern parts of the Indian Peninsula, in the south Deccan, Salem, Madura, Tinnevely, and Travancore, in dry forests, often occurring along with *A. Latronum*, and sometimes also with *A. arabica*, *Albizia amara*, *Dichrostachys cinerea*, *Chloroxylon Swietenia*, and a few others. Mixed with *A. Latronum* it forms at times a dense and impenetrable growth, but often it occurs in stunted form in open crops. In shape it exhibits the umbrella form characteristic of tropical open xerophilous woodland. The tree reproduces from root-suckers when felled ; in the Tinnevely district it is worked for the production of fuel as simple coppice on a rotation of fifteen years, reproduction being largely from root-suckers. Seedling reproduction is also said to be good in open places.

7. *Acacia Latronum*, Willd. Vern. *Odai* (also a name given to *A. planifrons*), *odai usal*, Tam. ; *Jala*, Tel.

A gregarious very thorny shrub or small tree resembling *A. planifrons* in its spreading umbrella-like crown, but smaller than that species. It is common in the dry parts of the Deccan and southern India, covering considerable stretches of country with a dense impenetrable thorny scrub, and often growing on bare hard gravelly soil, both on flat ground and on the lower hill slopes, where it may perform a useful function in preventing erosion and in protecting young plants of other species from injury by browsing. It is readily browsed by goats itself, though its thorns afford a formidable protection. The thorns are of two kinds, one large, white, conical and hollow, often tenanted by large black ants, and the other shorter and slender. Among its more common associates are *Acacia planifrons*, *A. leucophloea*, *A. arabica*,

¹ Ind. Forester, iv (1879), p. 387.

Albizzia amara, *Randia dumetorum*, *Azadirachta indica*, *Dichrostachys cinerea*, and *Chloroxylon Swietenia*. On poor soils it is sometimes associated with *Acacia eburnea*, *Balanites Roxburghii*, and *Capparis aphylla*.

8. *Acacia Farnesiana*, Willd. Syn. *Vachellia Farnesiana*, W. and A. Cassie flower. Vern. *Wilayati babul*, *wilayati kikar*, *gukikar*, Hind.; *Jalli*, Kan.; *Kankri*, Mar.; *Nanlongyaing*, Burm.

A thorny shrub or small tree reaching a height of 15 ft. or sometimes more, with fragrant flowers from which a perfume is extracted; it yields a gum. Indigenous in tropical America; cultivated and self-sown throughout the greater part of India and Burma. In northern India it is sometimes found gregariously in river-beds on loose sandy soil, a condition which appears to favour its establishment. On the plains of the Punjab it grows well on pure sand in fairly dry places, and would probably do well for sowing up shifting sands.

The flowering season is somewhat irregular, but lasts chiefly from November to March; the bright yellow globose flower-heads are powerfully scented. The pods form rapidly, and are usually full-sized but still green by May. They commence ripening about July (Dehra Dun), but hang long on the tree, and may be collected almost any time. The pods are 2-3.5 in. long by 0.5 in. thick, nearly cylindrical, pointed at both ends, turgid, dark brown when ripe, with a double row of numerous seeds embedded in dry spongy tissue; they are hardly dehiscent. About 300-340 seeds weigh 1 oz. The pods usually fall without dehiscing, and the valves become eaten by insects or decay or are beaten open by heavy rain, the seeds being washed out. The seeds often germinate within the pod; a dense clump of seedlings resulting. Germination takes place during the rains, but many seeds remain on or in the ground for a whole year, germinating in the second rains. At Dehra Dun the season's growth ends about December; the leaves commence falling in November-December and the plants are leafless or nearly so in January-February, the new leaves appearing in February-March.

Under favourable conditions the growth of the seedling is rapid. Seed sown at Dehra Dun in May in a nursery-bed regularly watered and weeded produced plants up to 7 ft. high by the end of the first season, and these flowered early the next year. In another plot seedlings regularly weeded but not watered reached maximum heights of 2 ft. 1 in. and 7 ft. 10 in. by the end of the first and second seasons respectively, and by the end of the third season the dominant plants varied from 7 ft. to 14 ft. 4 in. in height; they commenced flowering in the end of the second season and the pods ripened successfully in the third season, the plants being then about two years old. The plants require free growing space, and the smaller ones are quickly suppressed and outgrown by the more vigorous ones. They stand frost fairly well.

9. *Acacia eburnea*, Willd. Syn. *Mimosa eburnea*, Roxb. Vern. *Pahari kikar*, Hind.; *Marmati*, Mar.; *Odai vél*, *kal odai*, Tam.

A large shrub or small tree with rough dark grey bark, sparse greyish foliage and straight spines, the larger ones white and up to 2 in. long. Though nowhere abundant, it is widely distributed in the drier parts of India, extending westward into Arabia. In the sub-Himalayan tract it occurs in dry river-beds along with *A. Catechu*. In the Indian Peninsula it is found in open thorn

forests on dry stony soil, associated with *A. Catechu*, *A. Latronum*, *A. leucophloea*, *Prosopis spicigera*, and other species, and on the poorest ground with *Balanites Roxburghii* and *Capparis aphylla*. It is associated with *Acacia arabica* on black cotton soil, but where this gives place to shallow *murram* or calcareous soil with rock or a clay stratum near the surface it replaces that species.

The yellow flower-heads, which have a somewhat unpleasant odour, appear from November to March, and the pods ripen from April to June.

10. **Australian acacias.** Three important Australian acacias, *A. decurrens*, Willd., *A. dealbata*, Link, and *A. Melanoxyton*, R.Br., have been introduced into India, chiefly in the Nilgiris, but to some extent also in the Himalaya and other hill tracts. In the Nilgiris they have become such a feature in the landscape that a brief account of their introduction and propagation in these hills will not be out of place.

A general description of the topography and climate of the Nilgiris will be found under *Eucalyptus Globulus*, the exotic tree *par excellence* in that region. Australian acacias appear to have been introduced first in the early forties of last century, mainly with the object of providing fuel, of which there was a great shortage at that time. Although as plantation trees they have been outclassed by *Eucalyptus Globulus*, still the acacias—chiefly *A. dealbata* and *A. Melanoxyton*, and to a smaller extent *A. decurrens*—were extensively planted, partly in mixture with eucalyptus and partly alone. The actual area of pure acacia plantations owned by Government in 1912 amounted to 322 acres ; in addition there are considerable areas of eucalyptus and acacias mixed, at elevations varying from 5,000 to 8,300 ft. These acacias are also to be found along roadsides, on waste land, in private plantations, and in gardens. *A. dealbata* has spread by root-suckers to such an extent as to become in many cases a nuisance.

The acacias appear to have been propagated from transplants and not by direct sowings, and this system has answered well. Spacings of 6 ft. by 6 ft. to 9 ft. by 9 ft. have been the general rule in plantations. The Government plantations, whether pure or mixed with eucalyptus, are worked for the production of fuel under the system of simple coppice. The rotation adopted until recently was one of ten years, but in 1913 it was raised to fifteen years. Under the coppice system, *A. Melanoxyton* is gradually dying out, and in a few unimportant cases it is being maintained, where pure, as high forest. Where acacia is mixed with eucalyptus the resulting crop becomes a two-storied coppice, owing to the more rapid growth of the eucalyptus.

The following particulars regarding the three acacias in question may be of interest :

(1) *Acacia decurrens*, Willd. Green wattle. An evergreen tree ; bark olive green when young, dark grey on older trees. Branchlets and foliage nearly glabrous and not hoary ; decurrence of leaf-stalks very marked. Flowers paler yellow and less plentiful and less strongly scented than in *A. dealbata* ; pods narrow and constricted between the seeds. Maiden describes six varieties, but admits that the gradations from one to another are slight. Var. *mollis*, Lindl., has tomentose foliage, but the pubescence on the branchlets is golden yellow ; this variety is regarded in Australia as the best tannin producer

among the acacias, and Maiden quotes yields of 32 to 36 per cent. of tannic acid in bark samples. Analyses of Nilgiri bark samples of the typical variety made at the Indian Institute of Science in 1912 gave 24.42 per cent. of tannin. In India it is nowhere plentiful enough to yield regular supplies of bark in quantity.

This species (or variety) is a native of Queensland, New South Wales, Victoria, and Tasmania. It is far less plentiful in the Nilgiris than *A. dealbata*; it has been planted in fair abundance along roads in Coonoor, but is not so common at Ootacamund, and is comparatively rare in the plantations. Its general habits in the Nilgiris are somewhat similar to those of *A. dealbata* described below; it reproduces well by coppice-shoots and root-suckers, but not so freely as that species. Its growth is more erect than that of *A. dealbata*.

(2) *Acacia dealbata*, Link. (*A. decurrens*, Willd., var. *dealbata*, Von Mueller ex Maiden.) Silver wattle. An evergreen tree with grey, sometimes silvery bark. Young branchlets angled, hoary, covered with minute pubescence; foliage also hoary. Flower-heads in profuse axillary and terminal panicked racemes, globose, about 0.15–0.2 in. in diameter, deep saffron yellow, strongly scented. Pods straight or curved, flattened, 2–3 in. long by 0.25–0.5 in. broad, broader and less constricted between the seeds than in *A. decurrens*: decurrence of leaf-stalks less marked than in the latter. Maiden regards *A. dealbata* as merely a variety of *A. decurrens*.

In Australia it ordinarily attains a height of 50 ft. and a girth of 3–6 ft.; in Tasmania a tree has been recorded about 100 ft. in height and 11 ft. 2 in. in girth. In the Nilgiris it seldom attains a height of over 40 ft. or a girth of over 4 ft. In Australia the timber is considered of little value, and is used chiefly for making cheap cask-staves. In the Nilgiris it is used as fuel, for which purpose it is considered good. The bark is not so rich in tannin as that of *A. decurrens*. Maiden says that in Australia the best samples of bark contain about 25 per cent. of tannic acid. Analyses of Nilgiri bark made at the Indian Institute of Science in 1912 showed 9.56 per cent. of tannin.

The tree is a native of New South Wales, Victoria, Queensland, and Tasmania. It has been extensively planted in the Mediterranean Riviera and elsewhere. In India it has become thoroughly naturalized in the Nilgiri and Palni hills, and has been planted in the Himalaya.

In the Nilgiris this tree, together with the blue gum, is one of the most characteristic features of the vegetation from 5,000 ft. upwards. One of its most striking peculiarities is its extraordinary power of reproduction by root-suckers, which come up in dense masses of thin whippy shoots, and spread with great facility. For this reason it is almost unrivalled as a means of clothing unstable hill slopes; in the neighbourhood of gardens, however, it is an intolerable nuisance owing to its powers of spreading and the difficulty of eradicating it, which is possible only by deep hoeing and extraction of all the roots. Another peculiarity of this tree in the Nilgiris is its straggling and sometimes almost recumbent habit of growth, erect trees being quite exceptional. It is very liable to breakage from wind. In the Nilgiris it has proved an excellent under-story to the eucalyptus in the grass-land type of plantations, where a soil-protective undergrowth is desirable: it appears to stand the light shade of the eucalyptus well, and reproduces freely by coppice. Fig. 174



FIG. 174 Coppice of *Eucalyptus Globulus* and *Acacia dealbata*, 6 years old, the latter forming an underwood to the former Coonoor Peak plantation, Nilgiris.



Fig 175 Coppice of *Acacia dealbata*, with younger coppice intermingled with numerous root-suckers in foreground. Nilgiris.

shows a crop of *Eucalyptus Globulus* coppice with *Acacia dealbata* coppice as an under-story, and Fig. 175 shows pure coppice of acacia, in which numerous root-suckers are intermingled. The tree has been found to have a powerful nitrogenizing action on the soil, and is thus a good natural fertilizer. In France it is said not to thrive on soil containing lime; the soil of the Nilgiris is particularly free from lime, and this may possibly favour its extraordinary vegetative activity on those hills.

As regards the yield of plantations, Mr. S. Cox¹ points out that it is hardly possible to give accurate figures for *A. dealbata* by itself, as it has been universally planted with *A. Melanoxyton*, and although in the plantations regularly coppiced for fuel the latter has largely died out there is always a small proportion left. Allowing for error caused by the mixture of the two species, the general average yield of coppice from ten to fifteen years old in the second rotation may be said to be from 2,000 to 3,000 cub. ft. stacked per acre.

The tree has been commonly planted in the Himalaya, for example at Simla and in the Naini Tal and Almora hills, chiefly between 6,000 and 8,000 ft. elevation. It suffers considerably from snow-break, but where its value lies in its adaptability for afforestation purposes this is not a serious drawback. In the abnormal frost of 1905 it suffered to a considerable extent, particularly at the higher elevations, but the check to the growth resulted in the production of numerous root-suckers. In the Naini Tal hills it stood the abnormal drought of 1907 and 1908 well where most other exotic species were badly damaged. In the Himalaya the tree flowers from January to March, and the seed ripens in June: in cold situations the fruit fails to ripen. When in flower the trees, laden with yellow blossom, are a striking sight.

(3) *Acacia Melanoxyton*, R.Br. Australian blackwood.

An evergreen tree, in its natural home ordinarily reaching a height of 60 to 80 ft. and a girth of 6 ft. Exceptionally it is said to reach a height of 120 ft. and a girth of 10 ft. In the Nilgiris it often reaches a height of 80 ft., but seldom attains a girth of over 5 ft. On rich soil it grows luxuriantly: thus in the Rallia plantation near Coonoor, where it is mixed with *Eucalyptus Globulus*, occasional trees reach a height of 110 ft. at an age of forty years, though the girth averages less than 3 ft., the trees having been drawn up to height by close planting (see Fig. 176). The largest recorded measurements in the Nilgiris are those made by Mr. Cowley-Brown in the case of a tree forty-nine years old in Bleak House plantation; these are: (1) height 127 ft., (2) girth at breast height 6 ft. 4 in., (3) estimated volume 212.5 cub. ft. (timber only). This tree has since been killed by *Loranthus*. Trees fifty-two years old in the Marlimund block on deep moist soil measured up to 100 ft. in height and 5 ft. in girth.

Acacia Melanoxyton is a larger tree, with more erect habit, straighter bole, and denser crown, than *A. decurrens* or *A. dealbata*. The dense olive-green foliage, consisting mainly of phyllodes and not of true leaves, forming a symmetrical tapering crown reaching low down, makes it one of the handsomest of the exotic trees in the Nilgiris; its general appearance is unlike that of a typical acacia. The young branchlets are angled, minutely grey tomentose, rarely glabrous. Phyllodes coriaceous, glabrous, lanceolate or oblong, usually

¹ Working Plan for the Nilgiri Plantations, 1913.

falcate, variable in size, usually 2.5–4 in. long by 0.3–0.8 in. broad. True bipinnate leaves often present, especially on young trees. Flower-heads 3 to 4 in axillary racemes, globose, yellow, about 0.2 in. in diameter. Pods linear, flat, often curved in a circle, 2–4 in. long by 0.3–0.4 in. broad. Seed small, with a long pale red funicle which encircles it.

The timber is of very good quality, dark brown, beautifully mottled, and is used in Australia for furniture, gunstocks, railway carriages, and other purposes. In the Nilgiris there is little demand for it for such uses. Analyses of Nilgiri bark at the Indian Institute of Science in 1912 gave 7.04 per cent. of tannin.

The tree is a native of Tasmania, Victoria, and New South Wales, and extends into South Australia and Queensland: it grows typically on rich soil. It has been fairly extensively planted in the Nilgiris, where it does well on fertile soil, but it is slowly dying out, partly owing to its susceptibility to the attacks of a *Loranthus*, which kills off numbers of trees, and partly to the fact that its coppicing powers are feeble. It reproduces by root-suckers, but not to the same prolific extent as *A. dealbata*. On deep moist fertile soil its growth is fairly rapid, as the figures quoted above show. Mr. D. E. Hutchins found in 1883 that trees in the Nilgiris gave about four rings per inch of radius and an annual increment of about 5 to 6 tons of wood per acre.

4. ALBIZZIA, Durazzini.

This genus contains fourteen Indian species, all trees, some of which are of importance in Indian silviculture. Perhaps the most characteristic feature of the genus, as affecting the distribution of the seed, is the pod, which is thin, flat, and dry, developing rapidly after the flowering, but taking some time to ripen fully; in most cases dehiscence does not take place fully until after the pods fall, and as they fall chiefly in the hot season when dry winds are prevalent, they may be blown to some distance from the tree. In some cases, especially in *A. Lebbek*, the seeds are very liable to destruction by insects, and this probably explains to a considerable extent the absence of reproduction where such damage is prevalent. Germination is epigeous. Some species produce root-suckers freely, e. g. *A. lucida*, *A. mollis*, and *A. odoratissima*. The growth of some is extremely rapid, e. g. *A. moluccana* (not indigenous) and *A. stipulata*. The species vary in soil moisture requirements from *A. procera*, which thrives on moist and even swampy ground, to *A. amara*, which grows on poor dry soils in the Indian Peninsula.

Species 1. *A. Lebbek*, Benth.; 2. *A. stipulata*, Boivin; 3. *A. procera*, Benth.; 4. *A. odoratissima*, Benth.; 5. *A. lucida*, Benth.; 6. *A. amara*, Boivin; 7. *A. mollis*, Boivin; 8. *A. moluccana*, Miq.

1. *Albizzia Lebbek*, Benth. Siris, East Indian walnut. Vern. *Siris*, Hind.; *Chichola*, Mar.; *Sirsul*, Kan.; *Dirasanam*, Tel.; *Vagai*, Tam.; *Kôkko*, Burm.

A moderate-sized or large deciduous tree; bark dark grey, rather rough with irregular cracks, red or crimson inside. In the open the tree forms a short bole, branching low down, with a broad crown, but in the forest

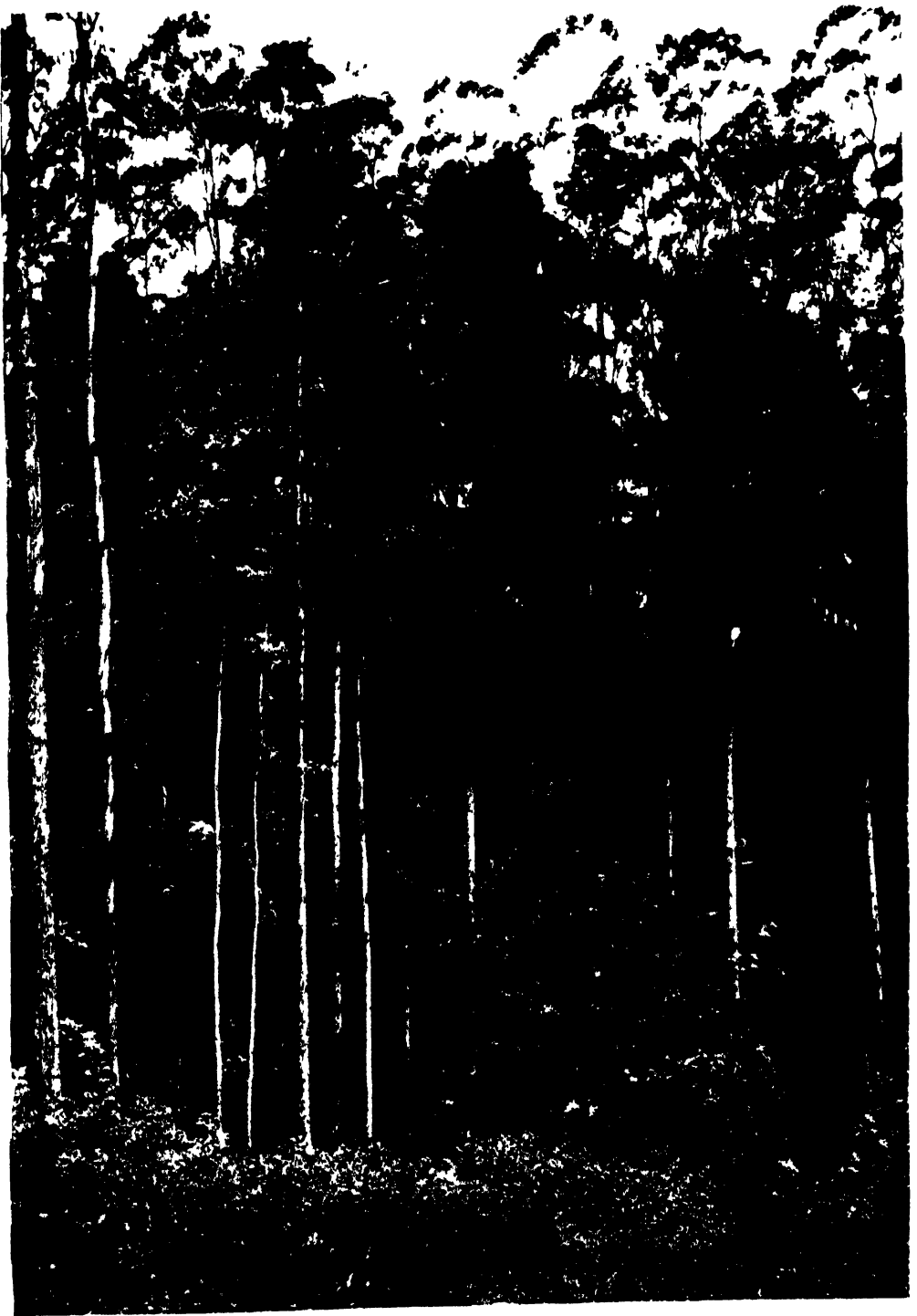


FIG. 176. Mixed plantation of *Eucalyptus Globulus* and *Acacia Melanoxydon*, 40 years old, Rallia plantation, Nilgiris.



FIG. 177. *Albizzia Lebbek* in evergreen forest, Andamans.

when drawn up by other trees it produces a long straight bole. In the Andamans it is said to yield squares up to 50 ft. long with 3 ft. siding.

The sapwood is whitish and large, the heartwood dark brown with lighter or darker streaks, ornamental, used for building, furniture, agricultural and other implements, carving, turning, &c. The burrs are particularly valuable.

DISTRIBUTION AND HABITAT. The tree has been so extensively planted in gardens, along roadsides and in other places, from which it has probably run wild, that its natural habitat is difficult to determine. It is believed to be wild in the sub-Himalayan tract, Bengal, Chota Nagpur, the Indian Peninsula, Burma, and the Andaman and Cocos islands. In the Himalayan valleys it occurs up to 4,000 ft. or sometimes more, usually along the banks of streams. Haines has come to the conclusion that it is nowhere wild in the southern forest circle of the Central Provinces, though very commonly planted, but the tree often called *A. Lebbek* is *A. odoratissima*, Benth., var. *lebbekifolia* Haines. Talbot says it is scattered throughout the Bombay Presidency in dry and moist monsoon forests. It is undoubtedly wild in some of the Madras forests, and Bourdillon says it is wild in the deciduous forests of Travancore at low elevations. It is a tree of the mixed deciduous forests, in both dry and moist types, or of moist semi-evergreen or even evergreen forest, usually occurring scattered and not gregariously. In the Andamans it is a regular forest tree, and occurs not only in the semi-deciduous or padauk-bearing forest but also in the evergreen forest: in the former it is associated with *Pterocarpus dalbergioides*, *Lagerstroemia hypoleuca*, *Terminalia bialata*, *Bombax insigne*, *Sterculia alata*, *S. villosa*, *Myristica Irya*, *Artocarpus Chaplasha*, and other species, while in the evergreen forest its chief companions are *Dipterocarpus turbinatus* and other species of *Dipterocarpus*, *Planchonia andamanica*, *Artocarpus Chaplasha*, *A. Lakoocha*, *Myristica Irya*, *Calophyllum spectabile*, *Mesua ferrea*, *Hopea odorata*, *Mimusops Elengi*, *Baccaurea sapida*, and *Podocarpus neriifolia*. Fig. 177 shows a tree in evergreen forest.

Mr. F. H. Todd¹ notes that in the North Andaman its northern limit, except for occasional specimens, is the Balmi creek, and that it is particularly abundant in Interview and Bennett Islands, in which from valuation surveys he estimated the stock to be: (1) trees 6 ft. in girth and over, 7,820; (2) trees 4½–6 ft. in girth, 3,275; (3) trees 3–4½ ft. in girth, 3,275. He also mentions that in the North Andaman the tree grows best in the moist semi-evergreen forests, and though fairly numerous in the deciduous forests, it is usually somewhat stunted.

More recent estimates from enumerations by Mr. Bonig, in which Mr. Todd's figures are incorporated, give the following figures: ²

	Trees over 6 ft. in girth.	Trees under 6 ft. in girth.
North Andaman felling series	10,725	—
Middle Andaman felling series	18,133	21,624
Southern Andaman felling series	1,220	4,990

In Burma it grows in tropical forests as well as in mixed deciduous forests.

¹ Draft Working Plan for the Forests of the North Andaman, 1906.

² Working Plan Report of the Andamans Forest Division, 1916.

In the former Brandis¹ mentions it as one of the lofty deciduous trees towering above the evergreen trees, other large deciduous trees growing with it being *Xylia dolabriformis*, *Albizia stipulata*, *Tetrameles nudiflora*, *Pentace burmanica*, *Sterculia* spp., &c. It is found both in the moist upper mixed forests and in the dry mixed forests. In the former it is associated with teak, *Xylia*, *Lagerstroemia Flos-Reginae*, *Dipterocarpus alatus*, and many other trees, the chief bamboos being *Bambusa polymorpha* and *Cephalostachyum pergracile*. In the dry mixed forests its chief companions are *Pentacme suavis*, *Shorea obtusa*, *Buchanania latifolia*, *Dalbergia cultrata*, *Terminalia tomentosa*, *Phyllanthus Emblica*, *Dillenia pulcherrima*, *Cassia Fistula*, and others, sometimes with teak of comparatively small size; the chief bamboo is *Dendrocalamus strictus*.

In the dry forests of the Madras Presidency it is found chiefly along streams and in moist places. It is frequently planted in dry regions, and on a variety of soils; it grows successfully when planted on black cotton soil.

LEAF-SHEDDING, FLOWERING, AND FRUITING. In northern India the leaves commence falling in October and November, and some trees are almost leafless by the end of November. Some are still in full leaf during December. In some cases the leaves continue falling from December to the end of February or even into March. The new leaves appear in April or sometimes as early as March. Trees or branches which yield fruits in plenty become leafless earlier and remain leafless longer than those which do not.

The flowers, of a somewhat heavy fragrance, appear chiefly in April and May, sometimes earlier or later, and the masses of yellowish white blossom are conspicuous against the new foliage.

The fruits develop rapidly, and by August some are nearly full-sized. In northern India they approach maturity by October, though still green, and begin to turn yellow in November, ripening soonest on trees which have lost their leaves; by December or January the pods are all ripe. Farther south they ripen sooner. They hang on the tree as a rule until March, when they commence to be blown down, but many continue hanging through April and May, some exceptionally remaining on the trees as late as October, so that from July onwards old yellow pods may be seen hanging along with young green ones. Heavy rain from March onwards brings down the pods in quantity.

The ripe pods are straw coloured, 8-12 in. long by 1.2-2 in. broad, flat, thin, firm, linear-oblong, 6- to 12-seeded, the outlines of the seeds prominent on the outside. They rustle in the breeze with a characteristic sound which has been described as that of the frying of meat. On leafless trees they are often produced in great abundance, the trees having the appearance of being covered with dry light yellow foliage. The pods are dehiscent, but dehiscence does not as a rule take place until the pods have reached the ground, and may be tardy or only partial, the seeds remaining within the pod for a considerable time.

The seeds (Fig. 178, a) are 0.3-0.45 in. by 0.25-0.35 in., obovate or oblong, compressed, light brown, smooth, with a hard testa. Their weight varies considerably, from 140 to 350 (average 230) weighing 1 oz. Tests carried out

¹ Report on the Attaran Forests.



FIG. 178. *Albizzia Lebbek* SEEDLING $\times \frac{1}{4}$

a Seed b d Germination stage e g Development of seedling during first season

at Dehra Dun showed that the seed retains its vitality well for at least one year. though fresh seed has a higher percentage of fertility than seed which has been kept for a time ; seed kept for a year germinated more rapidly than fresh seed. The seeds are very subject to the attacks of insects, particularly of a small whitish caterpillar, and many are destroyed both on the tree and on the ground. Rain sometimes causes much of the seed to rot in the pods, particularly after they have fallen, and it is therefore advisable to collect the seed as soon after it ripens as possible. This can best be done by men ascending the trees and picking the pods off, or by knocking them off with the aid of a long stick ; in the latter case it is advisable to spread sheets under the trees, as much of the seed may fall out during the process. The seeds are extracted from the pods either by opening the latter or by crushing them in the hands and separating the seeds by winnowing.

GERMINATION (Fig. 178, *b-d*). Epigeous. The radicle emerges first, and the hypocotyl elongates by arching, soon straightening and carrying the cotyledons above ground ; as a rule the testa is carried up over the cotyledons, falling with their expansion, but sometimes it remains underground.

THE SEEDLING (Fig. 178).

Roots : primary root long, terete, tapering, wiry, brown : lateral roots moderate in number, short, fibrous, distributed down main root : nodules present. **Hypocotyl** distinct from root, 1.5–2 in. long, terete, tapering upwards, minutely pubescent. **Cotyledons** sessile, 0.6 by 0.4 in., elliptical ovate, apex rounded, base sagittate, flat or slightly plano-convex, fleshy, entire, green, glabrous. **Stem** erect, terete, wiry, green, pubescent ; internodes 0.1–0.5 in. long. **Leaves** alternate. Stipules minute, lanceolate. First leaf once paripinnate, rachis 0.6–1.3 in. long, leaflets opposite, five or six pairs, 0.4–0.7 in. by 0.15–0.17 in., obliquely oblong, subsequent leaves bipinnate, at first with one pair of pinnae 0.7–1.5 in. long, common rachis 0.5–1 in. long, the number of pairs of pinnae increasing subsequently.

The development of the seedling varies greatly among individual plants even under identical conditions, but there are certain factors which stimulate development, and which induce remarkably rapid growth from the commencement ; the most important factors are absence of weeds, loose soil, sufficient soil moisture, and full sunlight. Numerous experimental plots at Dehra Dun have demonstrated the marked effect of regular weeding and loosening of the soil on the growth of the seedling, and although watering has a beneficial effect it is of comparatively little avail unless weeding is carried out.

As regards light requirements, experimental plots of seedlings grown under shade of varying intensity have shown that dense shade greatly retards germination, some seed failing to germinate until the second year ; seedlings which do appear are capable of standing heavy shade for one season but not longer, and development is very slow, a maximum height of only 4 in. having been recorded at the end of the season. The seedlings develop satisfactorily with moderate side shade, but at Dehra Dun their growth was found to be inferior to that of plants grown in full sunlight. The following measurements recorded in various experimental plots at Dehra Dun exhibit the marked effects of regular weeding, whether accompanied by irrigation or not :

Albizzia Lebbek : rate of growth of seedlings in experimental plots.

Irrigated plots.		Unirrigated plots.	
Weeded.	Unweeded.	Weeded.	Unweeded.
Height at end of first season.			
(1) 1 ft. 2 in.—8 ft. 4 in. (nursery plants ; seed sown Feb. and early start obtained)	Maximum 1 ft. 5 in. ¹	Maximum 2 ft. 9 in. ¹	(1) Maximum 1 ft. 1 in. (2) „ 0 ft. 7 in. (3) „ 0 ft. 8 in. (4) „ 0 ft. 10 in.
(2) Maximum 2 ft. 0 in. ¹			
Height at end of 2nd season.			
(1) Maximum 14 ft. 4 in.	Maximum 4 ft. 5 in. ¹	Maximum 6 ft. 11 in. ¹	(1) Maximum 2 ft. 9 in. ¹ (2) „ 1 ft. 9 in. (3) „ 2 ft. 9 in. (4) „ 2 ft. 10 in.
(2) „ 6 ft. 8 in. ¹			
Height at end of 3rd season.			
(1) Abandoned	Maximum 11 ft. 0 in.	Maximum 14 ft. 9 in.	(1) Maximum 4 ft. 10 in. (2) „ 4 ft. 8 in.
(2) Maximum 13 ft. 0 in. (dominant plants vigorous)		(dominant plants vigorous)	

¹ Growth of seedlings retarded by attacks of *Oxyrhachis tarandus*, Fabr., a hemipterous insect of the family Membracidae which infests seedlings and saplings of this and other species of *Albizzia* as well as certain other leguminous species (to some extent *Acacia Catechu*), doing much damage by sucking the young shoots and causing them to wither ; the leading shoots are often destroyed in this way and the growth of the plants is seriously interfered with.

All the plots noted in the above statement were in full sunlight : the unirrigated unweeded plots may be taken to represent the development under natural conditions. Nursery-raised plants, regularly weeded and watered, show rapid growth from the commencement, and may attain a height of nearly 4 ft. in four months from germination. A long stout taproot is produced at an early stage ; this may reach a length of 2 ft. in three to four months. The lateral rootlets are often covered with rather large nodules. In northern India the leaves of seedlings fall from about December to March, and growth ceases during the cold season ; new growth commences about February.

The seedlings are not very frost-tender, though the leaves are apt to shrivel up in frosty localities before falling, and the leading shoots are sometimes killed back where frost is severe. Young plants are somewhat sensitive to drought, especially in the first season. If early rain stimulates germination and prolonged dry weather ensues, the young seedlings are killed off in quantity. Under natural conditions light weed-growth and grass, though it impedes development, acts as a protective against drought. The sudden removal of weeds from over young seedlings is fatal ; weeding requires to be carried out from the commencement. Seedlings do not stand suppression well, and where they are at all crowded the more vigorous individuals quickly suppress the more weakly ones.

SILVICULTURAL CHARACTERS. Young plants are capable of standing a moderate amount of shade, though their growth is interfered with if the shade is at all heavy. For its best development the tree requires full overhead light. It is not exacting as to soil, and will grow fairly well even on laterite or black cotton soil. The root-system is largely superficial, and though as a rule the tree does not produce root-suckers regularly, it may do so if the roots are exposed. Mr. G. M. Ryan writes : ¹ '*Albizzia Lebbek* is not a tree

¹ Ind. Forester, xxx (1904), p. 454.

which has been noticed to throw up root-suckers habitually, but a very interesting instance of such reproduction occurring on the exposure of the root-system came to my knowledge recently in the Wada Range (Thana district, Bombay), where 21 *Albizzia Lebbek* suckers were observed in some excavated pits arising from roots which were embedded to the depth of $1\frac{1}{2}$ ft. in the soil. A close examination proved that these suckers arose from a network of subterranean roots which spread out from an *Albizzia Lebbek* 100 ft. away.' Its shallow root-system renders it liable to be thrown by wind. The tree is browsed by camels and lopped for camel fodder. It is sometimes badly attacked by *Loranthus*.

NATURAL REPRODUCTION. Under natural conditions germination ordinarily commences early in the rainy season and may continue until late in the rains. If the seeds are exposed to full sunlight germination is usually prompt and complete, but under shade it is delayed, and seed may lie ungerminated until the following year. In full sunlight, however, there may be high mortality if dry weather occurs after rain during or shortly after germination, and the survival of the seedlings is surer in a moderate growth of grass and weeds than if they are fully exposed to the sun, though their development is impeded. The ideal conditions for natural reproduction appear to be loose fairly moist soil, free from weeds, under light shade preferably from the side, the shade being removed when the seedlings have established themselves.

The sporadic nature and uncertainty of natural reproduction in most localities is noticeable. Seedlings in various stages are occasionally met with, but considering the large quantities of pods produced natural reproduction is decidedly scanty. It is probable that insect attacks account for this to a large extent, and an experiment carried out at Dehra Dun appears to support this view. Pods which were knocked off the trees by heavy rain in March were placed on a plot of ground which had been previously dug up, germination being thus favoured. The pods, which were left uncovered as under natural conditions, gradually dehisced and the seed began to fall out in May, but by July every seed had become badly attacked by insects, and not a single one germinated, although the plot was kept under observation until the end of the year. Drought is no doubt also a fruitful cause of failure, in dry localities and on stiff or shallow soils, particularly during germination and in the early seedling stages. Heavy shade, in retarding germination and thus prolonging the period during which the seed is exposed to insect attacks, is another adverse factor.

ARTIFICIAL REPRODUCTION. *Albizzia Lebbek* can be grown by direct sowings and by transplanting from the nursery, but experiments at Dehra Dun showed the former to be the more successful, as transplanting checks the growth to some extent. It was found that transplanting could be carried out successfully either by pruning the root and stem or by leaving them intact; in the latter case it is advisable to use small plants during the first rainy season, owing to the length of taproot. If pruning is carried out the stem should be cut down to about 2 in. from ground-level and the taproot pruned to a length of about 9 in. The seed may be sown in the nursery in March-April in drills not less than 9 in. apart, the beds being watered regularly but moderately and kept well weeded; the young plants will be ready to transplant early in the rainy season.

For direct sowings the Dehra Dun experiments showed that line sowings on well-loosened soil, the lines being kept weeded from the commencement, gave the best results. Irrigation stimulates the growth, the seed being sown along the base of the ridge of loose earth thrown up alongside an irrigation channel $1\frac{1}{2}$ ft. by $1\frac{1}{2}$ ft. in section. In line sowings the seedlings require to be thinned out regularly.

Mr. L. S. Osmaston ¹ has described some experiments carried out in 1905 and 1906, in raising *Albizia Lebbek* artificially on shallow soil overlying trap in the Nasik district of Bombay, where the rainfall is about 24 in. The experiments and their results were briefly as follows :

1. Broadcasting without previous preparation of the soil. Seedlings of 1905 died ; those which failed to germinate in 1905 germinated in 1906, but the results in the latter case have not been recorded.

2. Dibbling : results similar.

3. Sowing on circular mounds :

(a) Large mounds $2\frac{1}{2}$ ft. high, 2 ft. diameter at top, and 7 ft. at base ; percentage of successful mounds, 100.

(b) Medium mounds 1 ft. to $1\frac{1}{2}$ ft. high, 2 ft. at top and 4 ft. at base ; percentage of successful mounds, 89.4.

(c) Small mounds 9 in. high, 3 ft. diameter at base ; percentage of successful mounds, 100.

4. Sowings in pits :

(a) All soil returned to pit ; percentage of successful pits, 37.

(b) Pits half filled with soil ; percentage of successful pits, 68.

(c) No soil returned to pit ; percentage of successful pits, 43.

5. Planting one-year-old transplants ; only 300 survived out of 7,000, or 4.3 per cent.

Mr. Osmaston further describes the conduct of line sowings in conjunction with the raising of field crops in the same locality : ² this system, which is explained under *Acacia arabica* (p. 437), proved quite successful, the plants in $3\frac{1}{2}$ years reaching a maximum height and girth of 18 ft. and 1 ft. $5\frac{1}{2}$ in. respectively. The Berar system, described under *Acacia arabica* (p. 435), should also prove suitable for the raising of *Albizia Lebbek*.

Mound sowings have proved successful in the Bellary district, Madras. The tree grows readily from cuttings.

SILVICULTURAL TREATMENT. As the tree occurs scattered in mixed forests it is in actual practice treated along with other species, usually either as coppice-with-standards or under selection fellings. In the Andaman forests it is regarded as one of the more valuable species ; under the existing working plan these forests are worked by selection fellings, the minimum girth limit for the felling of sound *Albizia Lebbek* being fixed at 6 ft.

As a general rule natural reproduction is so scanty that the only means of ensuring a plentiful and regular supply of this timber would appear to be by artificial cultivation.

RATE OF GROWTH. The growth is fast. The rapid development of young plants under favourable conditions has already been alluded to under 'the

¹ Ind. Forester, xxxiii (1907), p. 177.

² *Ibid.*, p. 265.



FIG 179. *Albizzia stipulata*, United Provinces.



FIG 180 *Albizia procera* growing gregariously on low-level savannah Goalpara,
Assam, *Bombax malabaricum* on extreme left

seedling'. Brandis says that trees in the Punjab reach a girth of 2 ft. 9 in. in twelve years and 4 ft. 6 in. in thirty years, and that trees seventeen years old at Sukkur in Sind reached a girth of 5 to 6 ft. These figures probably refer to trees grown in more or less open positions; in the forest the growth in girth would probably be slower.

2. *Albizzia stipulata*, Boivin. Vern. *Ohi*, Pb.; *Siran*, Hind.; *Chakua*, Beng.; *Sau*, Ass.; *Kalbage*, Kan.; *Laeli*, Mar.; *Konda chigara*, Tel.; *Pili vagai*, Tam.; *Bônmeza*, Burm. (Fig. 179.)

A large deciduous tree with feathery foliage and large stipules. The crown is often spreading and flat-topped. Bark dark grey, fairly smooth, with occasional prominent horizontal wrinkles and furrows and numerous small vertical wrinkles. Sapwood large, white; heartwood brown, soft, not very durable, used for building, furniture, domestic utensils, &c. It is used as a shade tree in tea plantations in Assam and the Bengal Duars.

DISTRIBUTION AND HABITAT. Throughout the sub-Himalayan tract and Himalayan valleys up to 4,000 ft., Bengal, Assam, Chota Nagpur, the moister parts of the Indian Peninsula, Andamans, Nicobars, Burma, Ceylon, and the Malay Peninsula.

The tree occurs chiefly in moist localities. It is common in the Kangra valley. In the sub-Himalayan tract and outer valleys it often occurs in swampy ground and moist low-lying savannahs. In the Peninsula it is found only in the moister regions, both on the west coast and in southern India. Bourdillon says it is very common in the lower open and deciduous forests of Travancore, ascending the hills to 3,000 ft. It occurs in the evergreen *sholas* of North Coimbatore (C. E. C. Fischer). Mr. F. H. Todd mentions it as one of the species in the semi-evergreen and deciduous forests of the North Andaman.¹ In Burma it is common in the tropical forests, in mixed forests both of moist and of dry types, and extends into the hill forests. Kurz² mentions it as one of the lofty deciduous trees towering above the stratum of evergreen trees in closed tropical forests. He also gives it as one of the trees of the pine (*Pinus Khasya*) forests of the hills, with *Daphnidium*, *Aperula*, *Helicia*, *Engelhardtia*, *Dillenia aurea*, *Ternstroemia japonica*, &c., and of the lower drier hill forests, of a rather stunted type, occupying exposed ridges at 3,000 to 4,000 ft. and upwards, associated with *Ternstroemia japonica*, *Schima Noronhae*, *Turpinia nepalensis*, *Bucklandia populnea*, *Dillenia aurea*, *Symplocos*, laurels, &c.

In its natural habitat the absolute maximum shade temperature varies from 95° to 110° F., the absolute minimum from 30° to 65° F., and the normal rainfall from 45 to 200 in. or more.

LEAF-SHEDDING, FLOWERING, AND FRUITING. Kurz³ and Haines⁴ say the tree is evergreen. In northern India it is deciduous, the leaves commencing to fall about January, shrivelling up and falling by single leaflets or by whole pinnae. The trees are usually leafless in February–March, the new leaves appearing in March or early April.

The masses of fragrant feathery yellowish white flowers appear from April to June amongst the rich green of the new foliage, and the tree is then

¹ Draft Working Plan for the Forests of the North Andaman. 1906.

² Preliminary Forest Report of Pegu, 1875.

³ For. Flora Br. Burma.

⁴ For. Flora Chota Nagpur.

particularly handsome. The pods while developing are pale reddish green : they commence ripening about November–December, and continue hanging in quantity through the leafless season, when they resemble small siris pods on the trees. They commence falling in quantity about March, and continue falling during the hot weather months, being blown to some distance from the trees by the dry winds : a few old empty pods may sometimes be found on the trees as late as September.

The pods (Fig. 181, *a*) are 3·5–6 in. long by 0·5–0·8 in. broad, flat, glabrous, light brown, often wrinkled over the seeds, 8- to 12-seeded. The majority of the pods dehisce after falling to the ground, the seed thus being distributed by the wind ; only those which remain late on the tree dehisce before falling. The seeds (Fig. 181, *b*) are 0·15–0·3 in. long, flat, ovate or elliptical, greenish brown, smooth ; about 900 weigh 1 oz. Tests at Dehra Dun have shown that the seed retains its vitality to some extent for at least a year, though the percentage of fertility of seed so kept is less than that of fresh seed.

GERMINATION (Fig. 181, *c–e*). Epigeous. After the emergence of the radicle the hypocotyl arches slightly, soon straightening and raising the cotyledons above ground. The testa is usually carried up over the cotyledons, falling with their expansion.

THE SEEDLING (Fig. 181).

Roots : primary root moderately long and thick, terete, tapering, wiry, white turning brown : lateral roots numerous, moderately long, fibrous, distributed down main root : nodules present. **Hypocotyl** distinct from root, 0·6–1·5 in. long, cylindrical or tapering upwards, expanded in a ring at the base, green or pinkish when young, minutely pubescent. **Cotyledons** sessile or very shortly petiolate, 0·3–0·4 in. by 0·15–0·2 in., elliptical or ovate, plano-convex, or slightly concave beneath, thin, somewhat fleshy, apex rounded, base sagittate, entire, glabrous. **Stem** erect, slightly zigzag at the nodes, green, minutely pubescent ; internodes 0·2–0·5 in. long. **Leaves**, first two sub-opposite or alternate, subsequent leaves alternate. Stipules 0·1–0·15 in. by 0·1 in. or less, falcate acuminate, caducous. First leaf usually once pinnate, sometimes bipinnate ; if once pinnate rachis 0·4–0·6 in. long, with about five pairs of leaflets 0·1–0·2 in. by less than 0·1 in., obliquely oblong or falcate, acute, entire, pubescent, glaucous beneath, midrib close to and parallel to one edge ; subsequent leaves bipinnate, first few with one pair, then a few with two pairs, then three pairs of pinnae, leaflets 4–20 pairs, up to 0·4 by 0·15 in., rachis with a gland on the upper side.

During the first season the seedling does not show that rapid growth which is such a marked feature later on. Seedlings raised under natural conditions on unweeded and unwatered ground at Dehra Dun showed the following growth in the first two seasons :

	Under moderate shade.	In full sunlight.
Height at end of 1st season	Chiefly 5–7 in.	Chiefly 5–8 in.
Height at end of 2nd season	Maximum 4 ft.	1 ft. 3 in.–4 ft. 9 in.

The seedlings stand moderate shade, but are killed by dense shade. They are capable of struggling well through a moderate growth of weeds and grass, though their development is stimulated by regular weeding as well as watering : seedlings regularly weeded and watered reached a height of 3 ft. by the end of the first season. Weeding, however, has to be carried out from the commencement, since if weeds are suddenly removed from over young seedlings

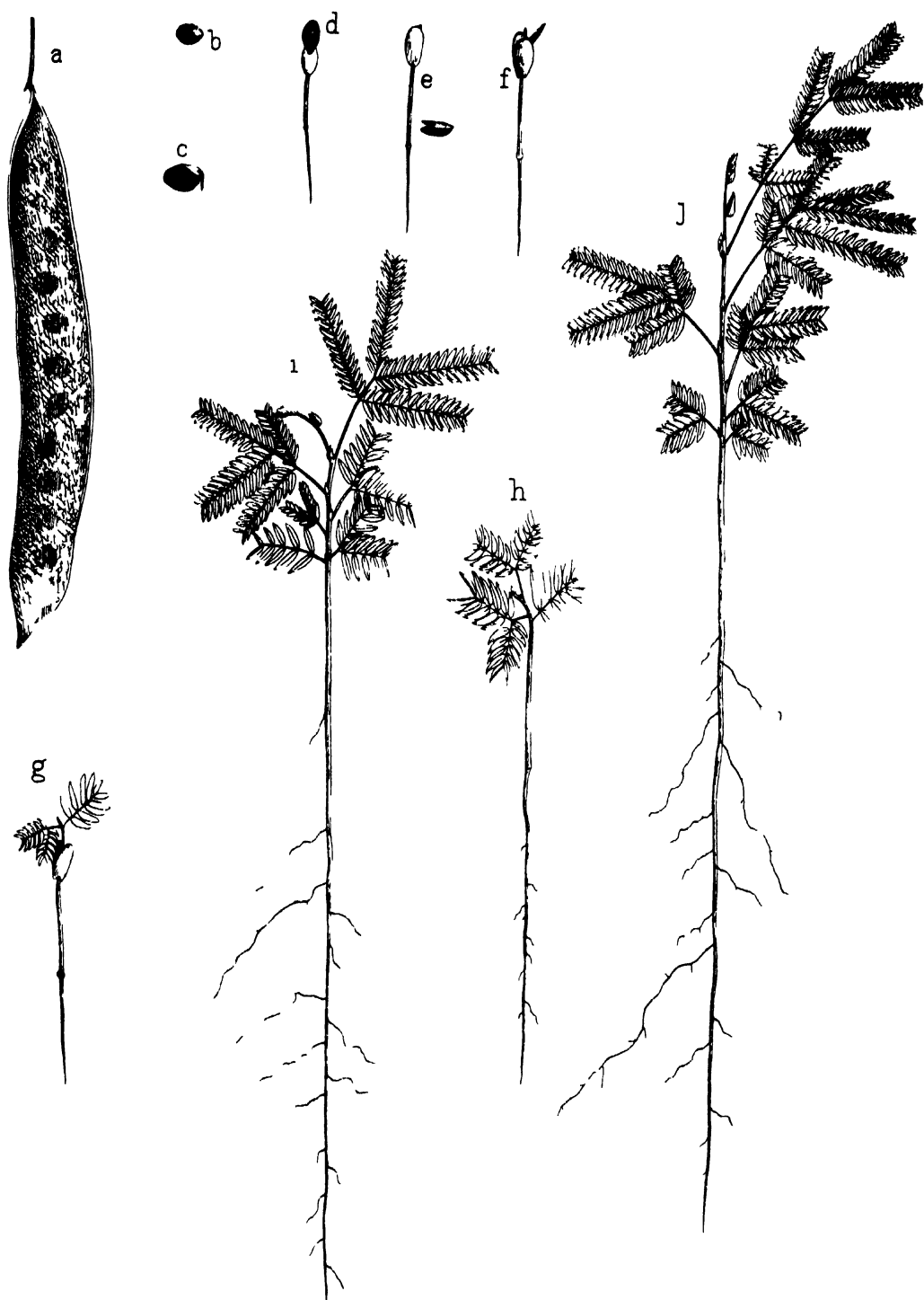


FIG. 181 *Albizzia stipulata* Seedling $\times \frac{1}{4}$.

a, fruit ; **b**, seed ; **c-e**, germination stages ; **f-j**, development of seedling during first season.

they are apt to die of drought. The seedlings are very sensitive to drought ; they are also somewhat sensitive to frost, though they have good power of recovery if killed back.

SILVICULTURAL CHARACTERS. Little is known of the silvicultural characters of this tree. It may be classed as a moderate light-demander ; that it is able to stand some shade is evident from the fact that it sometimes grows up in teak plantations in Burma and makes its way through the teak.

NATURAL REPRODUCTION. Germination starts early in the rainy season, and in warm sunny places is completed early. Under shade germination may continue throughout the rains and on till October or November, while some of the seed may lie dormant through the ensuing dry season, and may germinate in the second rainy season. The most favourable conditions for natural reproduction appear to be loose soil, in which the seed becomes covered during the early showers, and a fair degree of moisture. A moderate growth of grass and weeds is not harmful, though it may hinder the development of the seedlings to some extent ; in dry localities it is even useful in protecting them from drought.

ARTIFICIAL REPRODUCTION. Experiments at Dehra Dun have shown that direct sowing is more successful than transplanting, and regular weeding from the commencement stimulates growth ; in this respect line sowings give the best promise of success.

Transplanting can be carried out without much difficulty in the rains. The seed should be sown in the nursery about March or April in drills 9 in. apart, the beds being well watered and weeded through the dry season. The seedlings should be planted out during the rainy season ; they can be transplanted successfully after pruning down the stem to near ground-level and cutting the root down to a length of about 9 in. If unpruned plants are used they should be small, otherwise the taproot gives trouble.

RATE OF GROWTH. The growth is very rapid. In teak plantations in Burma the tree grows quickly through the fast growing teak and has to be cut out periodically in thinnings. Two cross-sections in the silvicultural museum at Dehra Dun, from trees in the United Provinces, showed the following rates of growth :

- (1) Age 28 years : girth 4 ft. 11 in. : mean annual girth increment 2.1 in.
- (2) Age 43 years : girth 4 ft. 6 in. : mean annual girth increment 1.25 in.

Gamble's specimens gave three to four rings per inch of radius, or a mean annual girth increment of 1.57 to 2.1 in. He also quotes the following measurements :¹ ' Roxburgh says that a tree he planted in the Botanic Garden at Calcutta measured 48.5 in. in girth at 4 ft. above ground when 7 years old ; this would give a rate of growth of slightly less than 1 ring per inch of radius. Stewart, in " Punjab Plants ", p. 56, says that a tree in the Saharanpur Gardens was 7 ft. in girth at about 17 years of age, which gives rather over 1 ring per inch of radius. . . . A round in the Bengal Forest Museum from a young tree shows 11 rings on a mean radius of 6 in., or 1.8 rings per inch of radius.'

3. *Albizzia procera*, Benth. Syn. *Mimosa elata*, Roxb. White siris. Vern. *Safed siris*, *gurar*, Hind. ; *Koroi*, Beng., Ass. ; *Bellati*, Kan. ; *Kinhai*, Mar. ; *Konda vagai*, Tam. ; *Chigara*, Tel. ; *Sit*, Burm.

¹ Man. Ind. Timb. (1902), p. 307.



FIG. 182. *Albizzia procera* SEEDLING $\times \frac{1}{2}$

a—Seed b - e Germination stages f - h Development of seedling during first season

A large tree with a long clean bole, often branching at a considerable height and forming a somewhat light crown. Bark smooth, light yellowish or greenish grey, exfoliating in thin flakes, red inside. The sapwood is large, whitish, the heartwood brown with streaks of darker or lighter colour, used for house-posts, agricultural implements, &c.

DISTRIBUTION AND HABITAT. Throughout the sub-Himalayan tract, common from the Jumna eastwards, Assam, Bengal, Chota Nagpur, the Indian Peninsula, Burma, and the Andamans. The tree is found most commonly on alluvial ground along streams and in moist, even swampy places; it is particularly common in low-lying moist savannahs, as in the Duars of Bengal and Assam, in Burma and elsewhere; in such places it is often gregarious, the clean light-coloured boles being very conspicuous (see Fig. 180). It is in many localities also a common species in mixed forests, generally on moist alluvial ground. In the Dehra Dun valley it is one of the constituents of the swamp forests, along with *Trewia nudiflora*, *Ficus glomerata*, *Pterospermum acerifolium*, *Cedrela Toona*, and other swamp species.

In its natural habitat the absolute maximum shade temperature varies from 98° to 115° F., the absolute minimum from 30° to 65° F., and the normal rainfall from 40 to 200 in.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The tree becomes almost leafless for a short time during the hot season, from April to June, according to locality: Haines¹ says there may be a second flush of new leaves in August growing through the flowering panicles. The large panicles of yellowish white flowers appear from June to September. The pods soon commence forming, and in the cold season, especially from October to January, they have a rich red colour, the trees at this time being particularly handsome with the masses of red pods against the green foliage. The pods ripen from February to May, and are then dark reddish brown, 4-8 in. long by 0.5-0.9 in. broad, thin, strap-shaped, 6- to 12-seeded, dehiscent. The seeds (Fig. 182, a) are 0.2-0.3 in. by 0.15-0.25 in., flat, elliptical to nearly orbicular, hard, smooth, greenish brown, with a leathery testa; about 500-850 weigh 1 oz.

The pods fall from the trees for the most part during the hot season, dehiscing before or about the time of falling. The seed germinates readily, and is less subject to insect attacks than that of *A. Lebbek*. It retains its vitality for at least a year; two tests of seed one year old at Dehra Dun showed 23 and 80 per cent. of fertility respectively.

GERMINATION (Fig. 182, b-e). Epigeous. After the emergence of the radicle the hypocotyl arches slightly, carrying the cotyledons above ground; the testa is either left on or in the ground, or, less commonly, carried up over the cotyledons, falling with their expansion.

THE SEEDLING (Fig. 182).

Roots: primary root long, at first thin, becoming fairly thick in vigorous plants, terete, tapering, wiry, whitish at first, becoming yellow or light brown: lateral roots few, somewhat short, fibrous, distributed down main root: nodules present. **Hypocotyl** distinct from root, 1.2-2 in. long, cylindrical, green or pinkish. **Cotyledons** sessile or sub-sessile, 0.35-0.4 in. by 0.2 in., elliptical, flat, somewhat fleshy, base sagittate, entire, green, glabrous. **Stem** erect, terete, wiry; internodes 0.2-1.5 in. long. **Leaves** alternate, compound.

¹ For. Flora Chota Nagpur.

Stipules minute, linear. First leaf compound, paripinnate, with rachis 0·6–1 in. long, terminating in a bristle, leaflets normally three pairs, opposite, shortly petioled, 0·4–0·6 in. by 0·15–0·25 in., obliquely ovate or obovate oblong, acute or obtuse, glabrous. Subsequent leaves bipinnate, leaves of the first season with one pair of pinnae, the number of pairs increasing later; common rachis and pinnae each 0·5–2 in. long; leaflets at first two or three pairs on each pinna, the number increasing to about ten pairs during the first season, opposite or sub-opposite, up to 1 in. by 0·3 in.

Under natural conditions the seedling usually attains a height of 4–8 in. by the end of the first season, but if regularly weeded and watered it grows rapidly, nursery-raised seedlings at Dehra Dun having attained a height of 1 ft. to 1 ft. 8 in. in three months from germination. The seedling is capable of struggling during the first season through low weeds and grass, its growth being slow during the process but increasing considerably after the weeds have been surmounted. The sudden removal of weeds from around seedlings previously unweeded, however, is liable to cause their death through sudden exposure to the sun. Vigorous seedlings produce long stout taproots which may reach a length of nearly 2 ft. in three months from germination: the lateral rootlets are usually covered with nodules.

The following measurements of seedlings in various plots at Dehra Dun will give some idea of the rate of growth under different conditions:

Albizia procera: development of seedlings.

Conditions under which grown.	Height at end of season.			
	1st season.	2nd season.	3rd season.	4th season
Nursery-raised trans-plants, entire stem and roots	(1) Maximum 0 ft. 6 in. (2) „ 1 ft. 4 in.	(1) 1 ft. 2 in.–3 ft. 4 in. (2) Maximum 3 ft. 1 in.	(1) 1 ft. 9 in.–7 ft. 5 in.	
Nursery-raised trans-plants, pruned stem and roots	Maximum 1 ft. 0 in.	Maximum 4 ft. 2 in.	2 ft. 10 in.–8 ft. 5 in.	
Natural conditions, unweeded, in full sunlight	(1) Maximum 0 ft. 6 in. (2) 4 in.–7½ in.	(1) Maximum 2 ft. 1 in. (2) 1 ft. 6 in.–2 ft. 5 in.	(2) 2 ft. 4 in.–8 ft. 2 in.	(2) Maxim 11 ft. 6 in
Natural conditions, unweeded, in moderate side shade	(1) Maximum 0 ft. 6 in. (2) „ 0 ft. 7½ in.	(1) 5½ in.–1 ft. 10 in. (2) 9 in.–1 ft. 8 in.		

The growth would in most cases have been greater except for the damage caused by the hemipterous insect *Oxyrhachis tarandus*, Fabr., which causes much injury to this species, as in the case of *Albizia Lebbek*. The seedlings are somewhat frost-tender, and are liable to be killed back in frosty localities. Growth ceases about November, and recommences about February–March. The leaves drop from December to February and the seedling is leafless for a short time.

SILVICULTURAL CHARACTERS. Although it stands moderate but not heavy shade in youth the tree may be classed as a light-demander, as it cannot stand suppression. In the abnormal drought of 1907 and 1908 in Oudh it proved fairly drought resistant, though in the moist localities in which it grows it was probably not as severely tested as species growing in drier tracts. In the great frost of 1905 in northern India it suffered severely. The tree is much subject to cankerous wounds, as a rule where branches have been broken

off. Mr. G. M. Ryan,¹ writing of conditions in Bombay, says the tree throws up root-suckers when the aerial portion of the stem has been mutilated or when an advanced age has been reached.

NATURAL REPRODUCTION. The natural reproduction of this tree is far more satisfactory than that of *A. Lebbek*. Germination takes place readily provided there is sufficient moisture, and in the forest seedlings may be found in quantity in the neighbourhood of seed-bearers during the rainy season, from seed which germinated early in the rains. Although the seed germinates more readily than that of *A. Lebbek*, in densely shaded localities the seedlings quickly die off, while in such places some of the seed may lie ungerminated until the second rains. The factors most favourable to natural reproduction are plentiful moisture and bare loose soil where the seed becomes buried with the early showers. Thus on new soft alluvial ground near rivers seedlings in all stages may often be found in abundance. Natural seedlings may also be found in some quantity in moist grassy tracts.

ARTIFICIAL REPRODUCTION. Experiments carried out at Dehra Dun have shown that transplanting can be carried out successfully in the rainy season, preferably during wet weather, with stem and root either pruned or left intact, but in the latter case transplanting is troublesome unless small plants of the first season are used. The seeds should be sown in nursery beds about March to May in drills about 9 in. apart, the seeds being placed a few inches apart in the drills and lightly covered.

Direct sowing has proved more successful than transplanting, provided regular weeding and loosening of the soil is carried out; line sowings have given greater success than any other form of sowing owing to the facility with which weeding can be carried out. This is a suitable species for growing in irrigated plantations or in line sowings in conjunction with the raising of field crops.

The tree grows readily from cuttings.

SILVICULTURAL TREATMENT. The tree is a useful one for afforesting low-lying savannahs and moist alluvial tracts. Although natural reproduction is often good near seed-bearers artificial reproduction would have to be relied on for complete stocking.

RATE OF GROWTH. The rate of growth is rapid. A cross-section in the silvicultural museum at Dehra Dun showed 26 rings for a girth, including bark, of 3 ft., giving a mean annual girth increment of 1.38 in. Brandis says that in northern India it attains a girth of 3-4 ft. in twelve years and 4-6 ft. in thirty years, giving a mean annual girth increment of 1.6 to 4 in. Gamble's specimens gave 6 rings per inch of radius, representing a mean annual girth increment of about 1 in.

4. *Albizzia odoratissima*, Benth. Syn. *Mimosa odoratissima*, Roxb. Black siris. Vern. *Karmaru*, Pb.; *Kali siris*, bansa (C. P.), Hind.; *Bilkumbi*, *bilwara*, Kan.; *Karu vagai*, Tam.; *Thitmagyi*, Burm.

A large tree with graceful drooping dark green foliage. Bark grey to yellowish grey, dark crimson inside. The dark brown heartwood is used for building, carts, wheels, furniture, &c. Haines² recognizes a variety *A. lebbekifolia* in the Central Provinces, with foliage very like *A. Lebbek* but distinguishable by the short peduncles, sessile flowers, and colour of the pods.

¹ Ind. Forester, xxx (1904), p. 454.

² *Ibid.*, xl (1914), p. 227.

DISTRIBUTION AND HABITAT. Sub-Himalayan tract and slopes and valleys of the Himalaya up to 5,000 ft., Bengal, Chota Nagpur, the Indian Peninsula, and Burma; also in the low country of Ceylon. The tree is widely distributed, being a common constituent of many types of mixed deciduous forest, where it grows sporadically. It is frequently found on hill slopes, and sometimes in valleys. In northern India it is common in the outer Himalaya and in the Siwalik hills: it extends throughout the greater part of the Indian Peninsula in dry as well as in moist deciduous forests. In Ajmer-Merwara it is one of the most important species, growing in dry forests on hill slopes with *Anogeissus pendula*, *Acacia Catechu*, *Boswellia serrata*, and other trees. In Burma it is common in the upper mixed forests with teak and its associates, extending into the drier types where the teak is associated with *Pentacme suavis*, *Shorea obtusa*, *Dalbergia cultrata*, *Phyllanthus Emblica*, &c. In Bombay it is common in the moist monsoon forests of North Kanara and the Konkan and also in the dry Deccan, ascending to 3,700 ft. in the Khandesh Akrani (Talbot). Bourdillon says it is common on grass-lands and in open forest throughout Travancore up to 3,000 ft.

In its natural habitat the absolute maximum shade temperature varies from 100° to 120° F., the absolute minimum from 30° to 60° F., and the normal rainfall from 25 to 120 in.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The leaves commence falling about December (northern India), and the new leaves appear in March–April. The tree sometimes becomes quite leafless for some little time, but more commonly the new leaves appear before the old ones have all fallen. The pale yellowish white fragrant flower-heads in large terminal panicles appear from April to June, and by October the pods are full-sized but still green: they commence ripening in December (northern India), or earlier farther south, falling during the hot season and dehiscing as a rule after falling, though some may hang for a long time on the tree, dehiscing before falling. When ripe the pods are 5–12 in. long by 1–1.3 in. broad, reddish brown or purplish green with darker markings over the seeds, flat and flexible, eight- to twelve-seeded.

SILVICULTURAL CHARACTERS. The tree stands a certain amount of shade in youth, but may be classed as a moderate light-demander. It is not exacting as regards soil, though on poor soil it is somewhat stunted. Its roots are largely superficial, and numerous root-suckers are produced. The young plants are susceptible to frost, and plantations formed in Ajmer-Merwara are reported to have failed for this reason. The tree coppices well, and in Ajmer-Merwara the shoots are said to reach a height of 10 ft. in two years, but are liable to be killed by frost: natural seedlings are reported to be plentiful in sheltered places where the soil is good.¹

RATE OF GROWTH. The only measurements available are those recorded by Mr. Gamble from wood specimens examined by him, the average of which showed 4 rings per inch of radius or a mean annual girth increment of 1.57 in.

5. *Albizia lucida*, Benth. Burmese siris. Vern. *Thanthat*, Burm.

A large tree with thin greyish bark and a full crown of handsome dark green foliage, the leaflets fewer and larger than in other species of this genus.

¹ Working Plan for the State Forests of Ajmer-Merwara, 1896.

DISTRIBUTION AND HABITAT. The sub-Himalayan tract from Nepal eastwards, eastern Himalayan valleys up to 2,000 ft., Assam, Chittagong, and Burma. The tree is often planted along avenues and in gardens outside its natural region, and grows well in Dehra Dun and other stations of northern India. It is found wild as a rule along the banks of streams and in moist places. In Burma it occurs in tropical forests where many of the species are evergreen, in lower mixed forests of the alluvial plains, and also in upper mixed deciduous forests.

In its natural habitat the absolute maximum shade temperature varies from 98° to 108° F., the absolute minimum from 35° to 55° F., and the normal rainfall from 45 to 200 in. or more.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The tree is leafless or nearly so for a short time in the early part of the hot season, about March; the leaves usually turn yellow before falling. The yellowish white flowers appear in April–May. The pods become full-sized about October–November, but are then unripe and green or reddish green; they ripen from February to April (observed ripening February in Bengal Duars, April in Dehra Dun). When ripe (Fig. 183, *a*) they are 4–8 in. long by 0.7–1 in. broad, light brown, flat, the seeds prominent. Most of the pods fall during the hot season, and dehisce as a rule after falling: they are carried by wind, with the seeds enclosed, to some distance from the tree. Some dehisce on the tree and a few of the open pod-valves may remain hanging as late as the following November. The seeds (Fig. 183, *b*) are 0.3–0.4 in. long, broadly elliptical or orbicular, light brown, flat, smooth, with a leathery testa: about 550–600 weigh 1 oz. The seeds germinate readily, but so far as tests at Dehra Dun go they appear to lose their vitality more quickly than those of other species of *Albizzia*.

GERMINATION (Fig. 183, *c–g*). Epigeous. After the emergence of the radicle the hypocotyl arches, soon straightening and carrying the cotyledons above ground: as a rule the testa is carried up over the cotyledons, falling off with their expansion.

THE SEEDLING (Fig. 183).

Roots: primary root moderately long, terete, tapering, flexuose: lateral roots moderate in number, fibrous, distributed down main root. **Hypocotyl** distinct from and thicker than young root, 1.2–1.8 in. long, terete, tapering slightly upwards, green, minutely pubescent. **Cotyledons** sub-sessile, 3.5–5 in. by 3–4 in., plano-convex, fleshy, elliptical orbicular, base sagittate, entire, glabrous, greenish yellow. **Stem** erect, wiry to woody. **Leaves**, first pair opposite, produced after a very short internode, thus emerging from between the cotyledons, subsequent leaves alternate. First pair simple or paripinnate with two or three pairs of leaflets or imparipinnate with five leaflets or bipinnate, one of the leaves often differing in form from the other. Simple leaves with petiole 0.1 in. long, lamina 0.8–1.2 in. by 0.3–0.4 in., ovate or elliptical lanceolate, acuminate, entire, glabrescent or minutely pubescent. Earliest compound leaves with rachis 0.5–0.8 in. long, leaflets opposite, very shortly petiolate, 0.5–0.8 in. by 0.2–0.4 in., ovate lanceolate, acuminate.

Seedlings raised at Dehra Dun showed only moderate growth during the first two years, nursery-raised transplants having a maximum height of 5½ in. and 14 in. by the end of the first and second seasons respectively. The seedlings proved very sensitive to drought, and grew best if well watered and kept shaded from the sun.

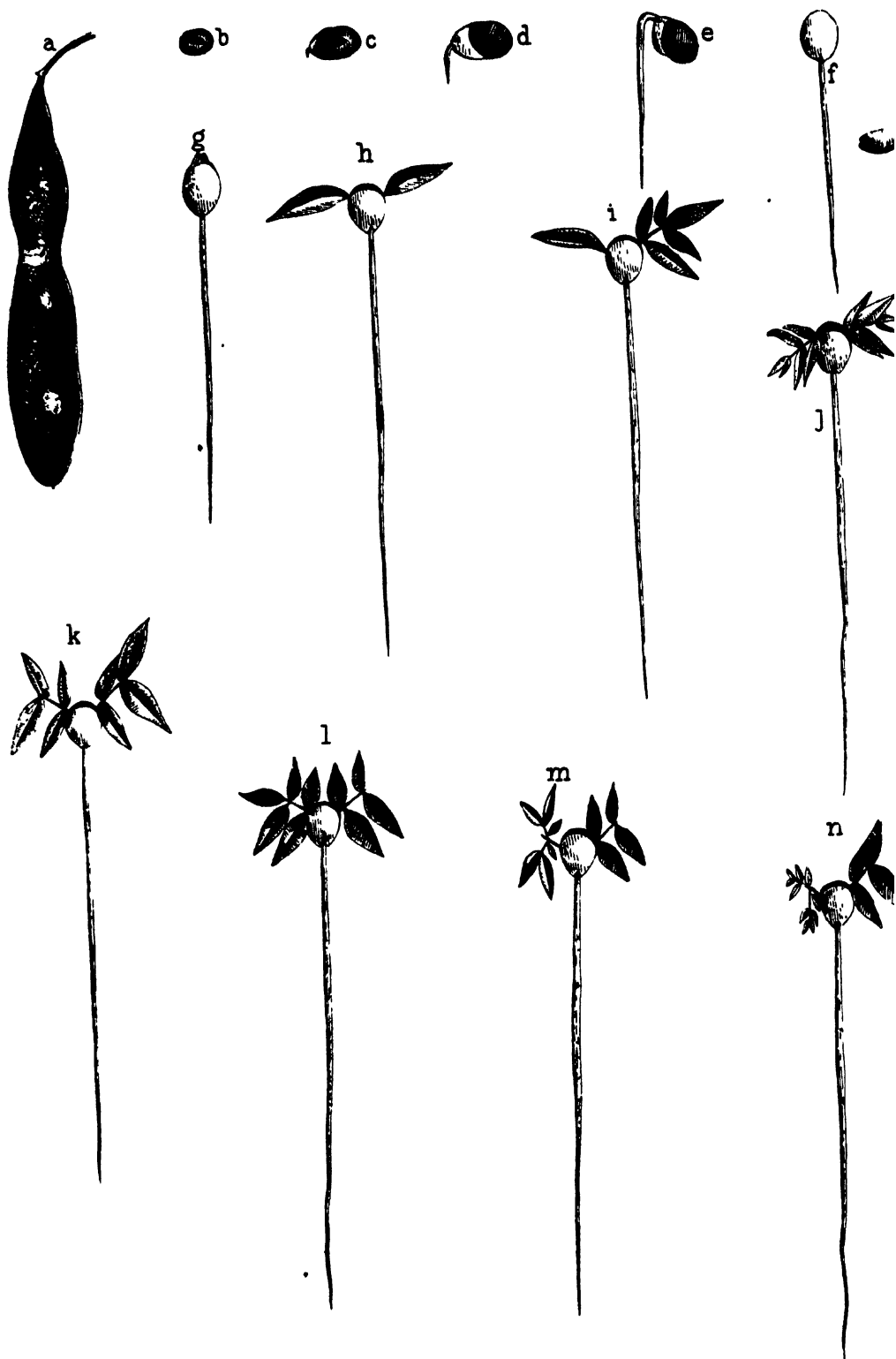


FIG. 183. *Albizia lucida*. Seedling $\times \frac{1}{4}$.
 a, fruit; b, seed; c-g, germination stages; h-n, early seedling stages showing variations in leaves.

SILVICULTURAL CHARACTERS. The silvicultural characters of this tree have not been studied in detail. It appears to be somewhat shade-bearing, and requires a moist situation for its best development. It has long spreading lateral roots near the surface of the ground, which produce a prolific crop of root-suckers to a considerable distance from the tree.

ARTIFICIAL REPRODUCTION. Experiments at Dehra Dun have shown that transplanting can be done without much difficulty both in the first and in the second rainy season, though this should be carried out as far as possible in wet weather. Fresh seed should be sown in the nursery-beds about March or April, the beds being kept well watered and weeded and shaded from the sun during the heat of the day. The transplanting of root-suckers is also recommended.

6. *Albizzia amara*, Boivin. Syn. *Mimosa amara*, Roxb. Vern. *Tugli, tugal*, Kan. ; *Lallei*, Deccan ; *Chikreni*, Tel. ; *Thuringi, unjai, usil*, Tam.

A small or moderate-sized much-branched deciduous tree with thin smooth dark greenish scaly bark. The leaves have numerous small leaflets. Heart-wood purplish brown, very hard, used for small building material, agricultural implements, &c., but chiefly for fuel.

A tree of the Indian Peninsula from Khandesh and Vizagapatam southwards, on dry often hilly country. Dry regions of Ceylon. On the Laun sandstone plateau in Raipur, Central Provinces (Haines). It is a common tree in the dry mixed deciduous and thorn forests of the Deccan. It is one of the most characteristic trees in the dry regions of the Madras Presidency, often growing on very poor soil ; among its chief companions are *Acacia Latronum*, *A. Catechu*, *A. planifrons*, *A. leucophloea*, *Chloroxylon Swietenia*, *Dichrostachys cinerea*, *Azadirachta indica*, *Anogeissus latifolia*, *Prosopis spici-gera*, *Cassia Fistula*, *Strychnos Nux-vomica*, *S. potatorum*, *Phyllanthus Emblica*, *Cleistanthus collinus*, *Terminalia Chebula*, *Zizyphus Xylopyrus*, and *Wrightia tinctoria*.

The tree reproduces freely from coppice-shoots and also produces root-suckers ; the coppice-shoots are often produced in such numbers that their size suffers and thinning is necessary. Natural reproduction by seed is usually good in areas protected from fire and grazing : goats are very partial to it, and it suffers much in grazed areas. The tree is usually worked as coppice or coppice-with-standards. It has been roughly estimated that coppice-shoots attain a girth of 2½ ft. in thirty years.¹

The yellow fragrant flower-heads appear from April to June and the pods ripen in the cold season, chiefly from November to January. The pods are 5–8 in. by 0·7–1 in., thin, flat, greyish brown, pubescent, veined, with undulate edges.

7. *Albizzia mollis*, Boivin. Syn. *A. Julibrissin*, Durazzini. Pink siris, hill siris. Vern. *Sirtin, lal siris, kuramura*, Hind.

A moderate-sized tree of the western Himalaya, ascending to 7,000 ft. The tree reproduces freely from root-suckers, and is useful for afforesting unstable hill-sides. The large pink tassels of flowers appear from April to June, at which time the tree is very handsome. The pods ripen from September to November, and remain some time on the tree : they are 3–5 in. by 0·6–0·9 in.,

¹ Tiruvannamalai Working Plan, South Arcot, 1902.

thin, yellow or light brown, eight- to twelve-seeded. The growth is fast; Gamble's specimens showed 3-4 rings per inch of radius, which gives a mean annual girth increment of 1.57 to 2.1 in.

8. *Albizia moluccana*, Miq.

A very large fast-growing Malayan tree with light foliage and a straight clean smooth grey bole, branching high up. It is largely grown in Ceylon and Java as a shade to coffee, and is worth cultivating as a quick-growing shade tree for other crops requiring light shade, as it is said to possess soil-improving properties. It has recently been grown on land cleared for tea in Assam, where in the Towkok garden, Sonari, Sibsagar district, trees four years from seed were reported in 1913 to have grown 46 ft. in height with a girth of 2 ft. 9 in. at 3 ft. from ground-level. Plantations of this tree have recently been formed in the Andamans, where it grows well even in exposed situations and is not affected by wind. Plants from seed sown in December 1912 attained by 1916 a height of 30 to 35 ft. and a girth of 1½ to 2 ft.; those on the soil of cleared evergreen forest attained in the same time a height of 40 to 45 ft. and a girth of 2-3 ft. at 3 ft. from ground-level. A tree in the Royal Botanic Gardens, Peradeniya, Ceylon, eleven years old, was 125 ft. high and nearly 11 ft. in girth at 2 ft. from the ground.¹ In Ceylon the pods ripen in May-June; the seeds are small, about 1,200 weighing 1 oz. The wood is soft and light, and suitable for tea-boxes and planking. Owing to its rapid growth it should be worth planting for this purpose in suitable localities.

5. *DICHROSTACHYS*, DC.

Dichrostachys cinerea, W. and A.

A thorny shrub or small tree with brown or grey longitudinally furrowed bark, found on dry stony ground in central and southern India, Rajputana, the Deccan and the dry zone of Upper Burma. It occurs also in Tinnevely, along with *Acacia planifrons*, on land regularly inundated by sea-water during the north-east monsoon, forming a dense impenetrable growth. In the dry regions in which it is commonly found the forest is usually of an open scrubby nature, situated both on hilly and on flat ground. In the Central Provinces it is frequent on black cotton soil. Silviculturally its chief importance in dry regions lies in the fact that it is very drought-resisting and reproduces freely by root-suckers, which are often produced at a considerable distance from the main stem owing to the long spreading lateral roots: thickets many yards in diameter are formed in this way. It is also comparatively immune from damage by grazing.

The plant resembles an acacia, having bipinnate leaves with minute leaflets. The inflorescences are striking, consisting of cylindrical spikes of flowers, the upper ones yellow and bisexual and the lower ones rose-coloured and sterile with long staminodes. The pods are 2-3 in. long, curled and twisted. The flowers appear and the fruit ripens at various times according to locality, during the hot season, the rains, or the cold season.

¹ *Cir. and Agr. Journ. Roy. Bot. Gardens, Ceylon*, Ser. I, No. 18, July 1900.

6. ADENANTHERA, Linn.

Adenanthera pavonina, Linn. Vern. *Munjuti*, Kan. ; *Anei*, *kundumani*, Tam. ; *Ywegyi*, Burm.

A handsome deciduous tree of the eastern sub-Himalayan tract, Burma, the Andamans, and the Western Ghats, often planted for ornament, especially in southern India. It attains a height of about 60 ft. The red wood is used for cabinet work and the scarlet seeds are used for jewellers' weights and necklaces. The tree requires a moist climate to thrive well, and can be grown easily from large cuttings put down early in the rains. The seeds are hard, and germinate with some difficulty unless kept moist for some days prior to sowing. The tree is leafless for a short time during the cold season. The small yellow fragrant flowers appear in the hot season. The pods are linear, narrow, about 6-8 in. long, twisting while opening and exposing the red seeds.

7. PITHECOLOBIUM, Martius.

Species 1. *P. dulce*, Benth. ; 2. *P. Saman*, Benth.

1. *Pithecolobium dulce*, Benth. Syn. *Inga dulcis*, Willd. ; *Mimosa dulcis*, Roxb.

A moderate-sized evergreen tree with stipular spines in pairs, a native of Mexico but commonly cultivated in India and Lower Burma as a hedge plant, and in southern India also as a fuel tree. On the coast of the Nellore district of Madras it has been planted on pure sand in the casuarina plantations as a safeguard against fungus disease in the casuarina. For hedges it is usual to sow the seed at site, and to trim the plants. The small globular heads of white flowers appear in January-February and the pods ripen from April to June ; the latter are 4-5 in. long by 0.3-0.4 in. broad, twisted, with black seeds embedded in a spongy edible pulp. The growth is fast. The tree coppices vigorously, and stands a good deal of shade. Parker¹ gives the following note regarding its susceptibility to frost in the Punjab :

'In Lahore it suffers considerably from frost. Seedlings planted in the Changa Manga Rest House Garden grown from seed received in 1912 from Sonora, Mexico, were uninjured by three nights' frost when the shade temperature sank to 27°, 27°, 26° F., although they were only a foot or so high and were quite unprotected. In 1914-15 plants from Indian seed were killed by frost in Lahore, but plants from Sonoran seed were uninjured, though they were not protected in any way. Hence it appears that the Sonora plant is a more frost-hardy variety than the one hitherto grown, which has not got beyond the South and Eastern portions of the Province owing to frost.'

2. *Pithecolobium Saman*, Benth. Rain tree.

A large tree with a broad spreading crown, branching low down and forming a short bole. A native of tropical South America, it has been largely planted along roadsides in some of the warmer parts of India, and particularly in Lower Burma, where it is one of the commonest roadside trees. It will not stand the colder parts of northern India, but elsewhere it is not particular as to soil, and will thrive even in comparatively dry climates, as at Mandalay, though it grows best in a moist climate. In the delta districts of Burma it

¹ For. Flora Punjab, p. 201.

is capable of growing in some of the wettest places, rapidly killing out grasses with its broad crown; it has therefore been suggested as a suitable tree for planting up grassy blanks in the fuel reserves in swampy localities, with the view of killing out grass and enabling other species of trees to be introduced afterwards. The pods contain a sweet edible pulp, and are readily eaten by cattle; the wood, however, is of little value. In Burma the flowers with their pink tufts of stamens appear in the hot season, chiefly in April and May, and the pods ripen from March to May. The growth is very rapid, and the tree is easily raised from seed; it can also be grown from cuttings.

8. LEUCAENA, Benth.

Leucaena glauca, Benth. Lead tree.

An unarmed evergreen large shrub or small tree, a native of tropical America and naturalized in other tropical regions of the world. It is planted in the plains of India, often as a hedge plant, and regenerates freely from self-sown seed. It occurs in the Phillaur plantation on the Punjab plains, where natural seedlings appear readily and stand a fair amount of shade. In the Philippines, where it is known as ipil-ipil, its growth in youth, according to Mr. D. M. Matthews,¹ is extremely rapid, seedling plants twenty-six months old varying from 3 to 5 cm. (1.2 to 2 in.) in diameter at breast height. It coppices vigorously and the growth of coppice-shoots is much more rapid than that of seedling plants, the shoots reaching a height of 5 m. (16.4 ft.) and a breast-height diameter of 5 cm. (2 in.) in one year. Coppice coupes one year old on well-drained soil were found to yield more than 90 stacked cubic metres per hectare (1,287 cub. ft. per acre), including brushwood of all sizes, while coupes two years old yielded up to 114 stacked cubic metres per hectare of material large enough for fuel, giving an annual production of 57 cubic metres per hectare or 815 cub. ft. per acre.

The utility of this species for afforesting grass-lands with the view of preparing the way for the introduction of timber trees has been proved in the Philippines. The dominant grass is *Imperata exaltata*, with which few species are able to compete owing to its dense mass of rhizomes and roots. The usual custom is to burn the grass immediately before the rainy season and to sow the *Leucaena* seed broadcast at the beginning of the rains: ploughing up the ground before sowing the seed is considered likely to give better results. Where seed is not sufficiently plentiful sowing in ploughed lines or transplanting from the nursery is suggested. The plant flowers and fruits at a very early age, good seed being produced by vigorous plants in the first or second year. In the Philippines the plant grows at comparatively low elevations in regions where the rainfall varies from 40 to 160 in. It is not particular as to soil, though it flourishes best on deep moist soil.

¹ Bureau of Forestry, Philippines, Bull. No. 13, 1914.

ORDER XXIV. ROSACEAE

This order is of little importance from a forest point of view, except that many of the species reproduce freely by means of root-suckers and are thus useful in clothing unstable hill-sides. This characteristic may, however, in some cases render them noxious weeds, as in the case of certain species of *Rubus* and *Rosa*, which form dense thickets in moist places, impeding the reproduction of forest trees. *Rubus lasiocarpus*, Sm., a scrambling shrub of the outer Himalaya, has an effective means of spreading by long flexible whip-like pendulous shoots which are produced in the rainy season and grow rapidly. The ends of these shoots are soft, and as soon as they come in contact with the ground they produce roots which quickly take a firm hold of the ground and in their turn produce new plants, a dense gregarious mass of interlacing brambles being formed in time. Of climbers, *Rosa moschata*, Mill., and *R. Leschenaultiana*, W. and A., deserve mention. The former is a common Himalayan species, often attaining considerable thickness and climbing to some height; although extremely handsome when in flower in the spring, it is often noxious to tree growth, causing suppression with its mass of scrambling branches and foliage. The latter is a large climber of the hills of southern India, very common in the Nilgiri sholas.

This order contains several important fruit trees grown in India, chiefly in the hills, namely *Prunus armeniaca*, Linn., the apricot; *P. persica*, Benth. and Hook. f., the peach; *P. communis*, Huds., the plum; *P. Amygdalus*, Baill., the almond; *P. Cerasus*, Linn., the cherry; *Pyrus Malus*, Linn., the apple; *P. communis*, Linn., the pear; and *Eriobotrya japonica*, Lindl., the loquat.

The Rosaceae are with few exceptions hill species, the majority Himalayan, several in the hills of southern India and some in Baluchistan and the hills of Assam and Burma.

Genera 1. PRUNUS, Linn.; 2. PYRUS, Linn.

1. PRUNUS, Linn.

Species 1. *P. Puddum*, Roxb; 2. *P. Padus*, Linn; 3. *P. nepalensis*, Hook. f.

1. *Prunus Puddum*, Roxb. Vern. *Padam*, Hind. Indian wild cherry.

A tree of the Himalaya, at 2,500-8,000 ft., Khasi hills and hills of Upper Burma, often cultivated. Bark greyish brown, smooth, shining, peeling off in thin horizontal strips like that of the common cherry. Gamble notes that there are two varieties of the tree in the Darjeeling hills: (1) a very large tree with crimson flowers which appear in March, and (2) a small or medium-sized tree with pink flowers which appear in October-November. The latter is the common one in the western Himalaya, both wild and cultivated. It is small or moderate-sized, producing clusters of pink flowers in the autumn or early winter, chiefly from October to December, though it occasionally flowers partially out of season, e. g. in July. The old leaves turn yellow and fall from October to December, the new flush appearing before the old ones have all fallen, and remaining fresh and green through the winter. The fruit, a yellow and red ovoid drupe 0.4-0.6 in. long, ripens chiefly from April to June. The

seeds are spread by birds. In Burma the tree is evergreen or nearly so, and this is also the case in the western Himalaya. When in flower it is very handsome. In the western Himalaya it is common in open village lands as well as in the forest. It stands a fair amount of shade, and may be found flourishing under the moderate shade of other trees, though it flowers best in the open. It reproduces fairly freely from root-suckers, and can be grown from cuttings; it forms a good stock plant for the common cherry.

2. *Prunus Padus*, Linn. Syn. *Padus cornuta*, Carr.; *Cerasus cornuta*, Wall. Bird cherry. Vern. *Páras*, *kalakat*, *zam*, Pb.; *Jamana*, *jamoi*, Jaunsar.

A moderate-sized or large deciduous tree with brown scaly bark. Wood with a handsome silver grain, suitable for furniture and deserving to be better known. In Europe it is usually a rather small tree, but in the Himalaya it attains a height of 60 ft. or sometimes more, and a girth of 6 ft. or over.

DISTRIBUTION AND HABITAT. This is the most widely distributed of all the species of *Prunus*, and is found throughout the greater part of Europe, in Siberia, Manchuria, North China, Japan, Persia, the Caucasus, and the Himalaya. In the Himalaya it is common chiefly at 6,000–10,000 ft., often occurring more or less gregariously on rather moist pasture grounds and in forest glades, associated with *Acer caesium*, *Aesculus indica*, *Ulmus Wallichiana*, and other broad-leaved species, as well as with conifers, particularly with yew (*Taxus baccata*), which in Hazara is often in the form of an underwood to it (see Fig. 185). It is particularly common in Hazara, where it attains very fair dimensions: on the higher ridges and grazing grounds at 9,000–10,000 ft., where it is plentiful, it is often associated with *Pyrus lanata*.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The leaves turn red and fall in the autumn, the tree remaining leafless during the winter and the new leaves appearing in the spring. The racemes of small white flowers appear from April to June, and the fruits, red to nearly black drupes about 0.4 in. in diameter, ripen from August to October. Fig. 184, *a*, shows the fruit-stone. The seed is disseminated by birds, which eat the fruits.

GERMINATION (Fig. 184, *b*, *c*). Epigeous. The fruit-stone splits in two, enabling the radicle to emerge. The hypocotyl elongates, carrying the cotyledons above ground, while the two halves of the fruit-stone are left on the ground.

THE SEEDLING (Fig. 184).

Roots: primary root moderately long, wiry, flexuose: lateral roots moderate in number and length, fibrous, distributed down main root. Hypocotyl distinct from root, 1.2 in. long, terete, fusiform or tapering upwards, red, minutely pubescent and tender when young, brown, glabrous and woody in second year. **Cotyledons:** petiole very short, flattened: lamina 0.25–0.3 in. by 0.15–0.2 in., plano-convex, fleshy, elliptical or obovate, entire, glabrous. **Stem** erect, slightly compressed, minutely pubescent; first internode, above cotyledons, 0.6–1.5 in. long, subsequent internodes of first season very short, leaves being crowded together. **Leaves** simple, first pair opposite, subsequent leaves alternate or sub-opposite, approximate. Stipules 0.2–0.3 in. long, linear acuminate, fimbriate. Petiole 0.2–0.4 in. long. Lamina 1–2.5 in. by 0.5–1 in., ovate lanceolate, acute or acuminate, base acute or tapering, serrate, glabrous, venation arched, veins prominent, depressed above, raised beneath, lateral veins 7–10 pairs.

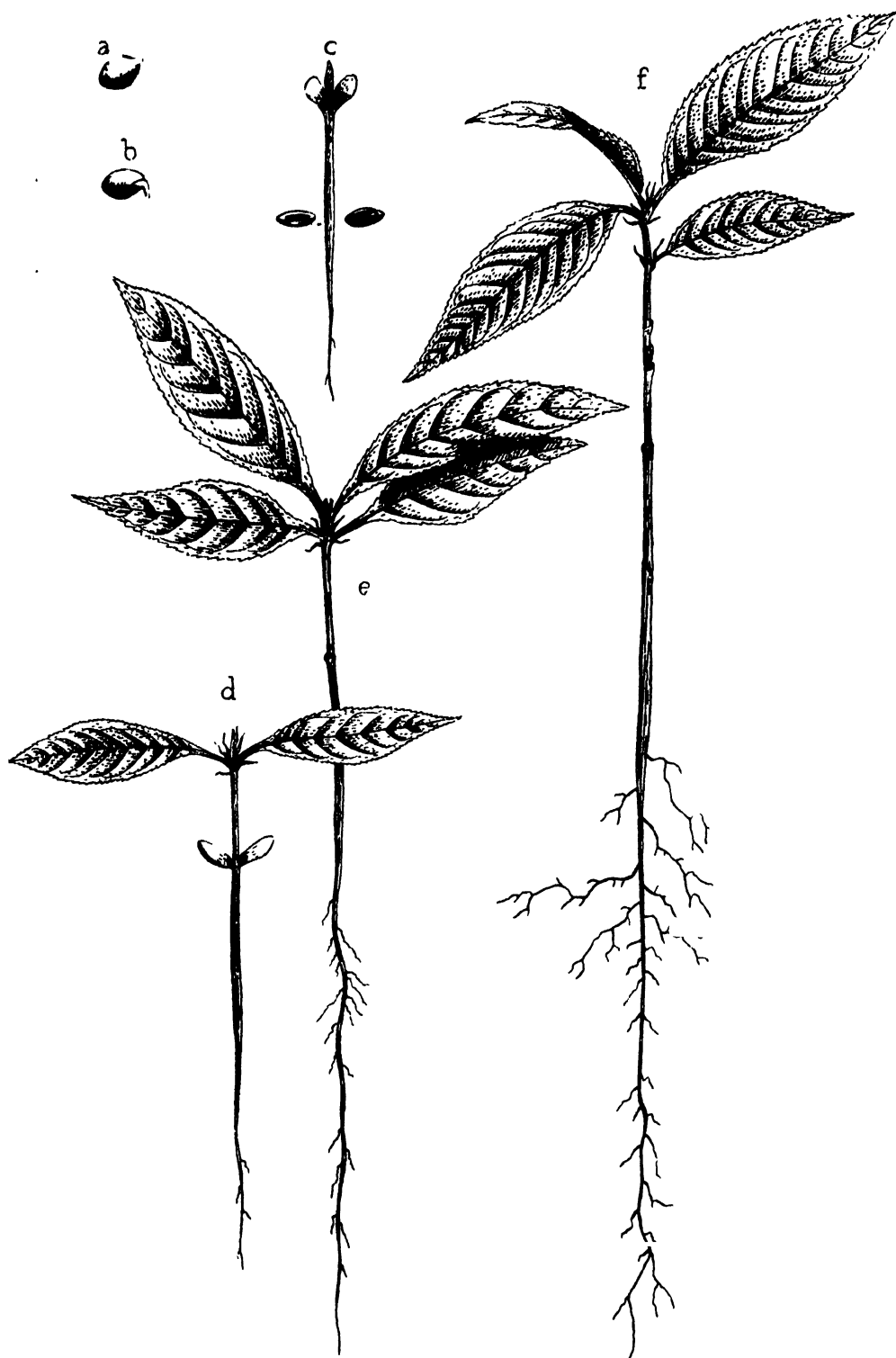


FIG. 184. *Prunus Padus*. Seedling $\times \frac{3}{4}$.

a, fruit-stone; *b*, *c*, germination stages; *d*, *e*, development of seedling during first season
f, seedling in second season.

The growth of the seedling is somewhat slow, natural seedlings attaining a height of about 3–5 in. during the first season and 9 in. to 1 ft. in three years.

SILVICULTURAL CHARACTERS. The tree is a moderate light-demander. It coppices well and produces root-suckers freely, especially when trees are felled or when the superficial roots are exposed and wounded. The branches are somewhat liable to be broken by snow.

NATURAL REPRODUCTION. Under natural conditions the seed germinates about April. Seedlings spring up in abundance on newly exposed ground, and particularly on deep loose rubble; natural reproduction may often be found in quantity on landslips and places recently eroded by snow.

3. *Prunus nepalensis*, Hook. f. Vern. *Arupatti*, Nep.

A large tree of the central and eastern Himalaya at 6,000–10,000 ft., Khasi hills, Upper Burma in evergreen forest in the Ruby Mines district at 6,000 ft. Bark greyish black, thin, smooth; branches verticillate. Mr. F. B. Manson¹ says the seeds, which are distributed by birds, germinate very easily in the end of February and the beginning of March, even when hoar-frost is frequent, and that the seedlings seem to thrive almost as well under cover as in the open, and are very common and useful for restocking blanks. He adds that the tree has an extensive range, but in the Darjeeling hills it thrives best between 6,000 and 6,500 ft.; here it grows quickly, and sound trees of 8 to 10 ft. in girth with fine straight boles are met with. In this locality the new leaves appear in March, the flowers in May, and the fruit ripens in October–November.²

2. *PYRUS*, Linn.

Pyrus Pashia, Ham. Syn. *P. variolosa*, Wall. Vern. *Patangi*, Hazara; *Káint*, *mehál*, W. Him.

A moderate-sized deciduous tree of the Himalaya at 2,000–8,000 ft., Khasi hills and hills of Upper Burma. In the outer Himalaya it is very common on open sunny slopes, often with *Quercus incana*, *Rhododendron arboreum*, *Berberis aristata*, *B. Lycium*, and *Pieris ovalifolia*, and lower down with *Pinus longifolia*, while at the base of the hills it is associated with low-level species, for example at Dehra Dun. It has spreading superficial roots and reproduces with great freedom from root-suckers, especially on hill-sides where the roots have become exposed; in this respect it is useful in preventing landslips. It can be grown from cuttings, and forms a useful stock for the apple. The leaves fall in November or early December, turning nearly black before falling, and the trees are leafless until the following March or April, when the new leaves appear; at low elevations they may appear as early as February. The white flowers appear with the new leaves, but occasionally trees may be seen flowering out of season, as late as July. The fruit is a globose five-celled pome 0.6–1.2 in. in diameter, greenish brown, covered with raised light grey dots, resembling a miniature apple, with brownish black shining seeds like small apple seeds. The fruits become full-sized by about July or August, but remain hard, with a firm whitish very astringent flesh until November–December, when the flesh begins to rot and turn black and sweetish:

¹ Working Plan for the Darjeeling Forests, 1893.

² Gamble, Darjeeling List.

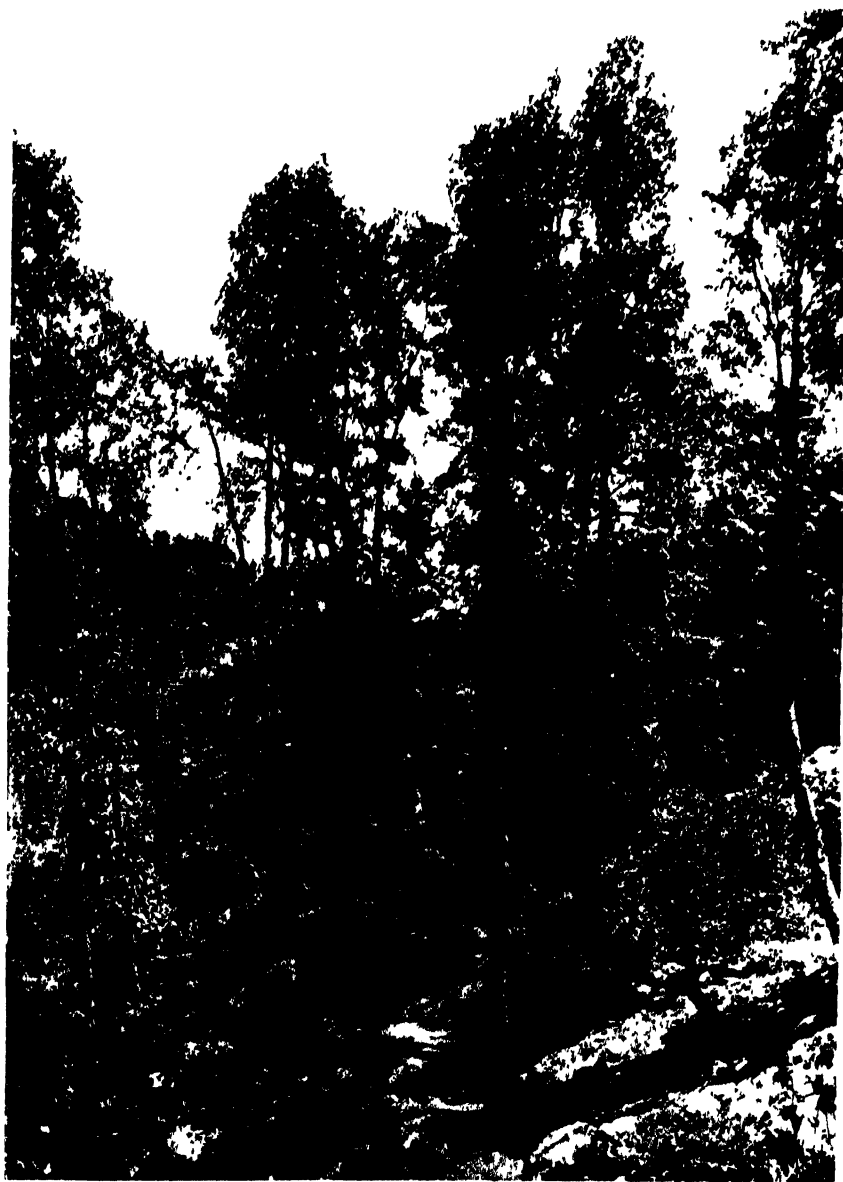


FIG. 185. *Prunus Padus* growing gregariously, with an underwood of *Taxus baccata*, Hazara.



FIG. 186. *Bucklandia populnea*, mature tree, girth 22 ft 6 in., height 140 ft., bole 85 ft., Darjeeling hills.

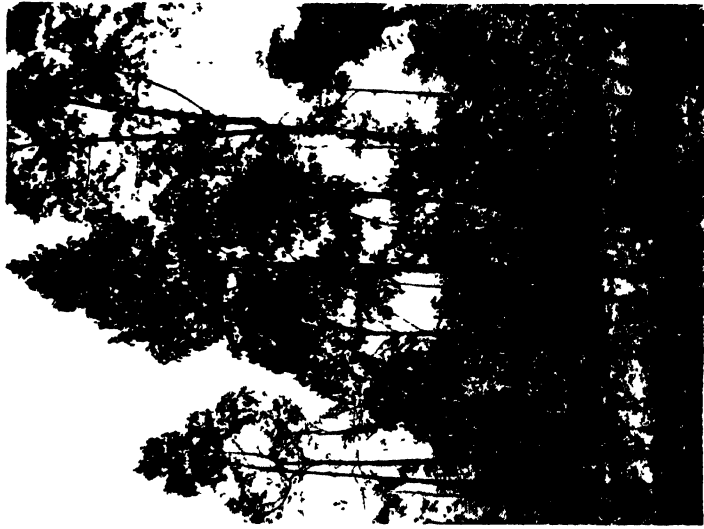


FIG. 187. *Bucklandia populnea*, pole (in centre with man at base) grown in sufficiently close crop to produce a clean bole, Darjeeling hills.



FIG. 188. *Bucklandia populnea* plantation between 20 and 30 years old.

they are conspicuous on the leafless trees during the earlier part of the winter. The fruits are left untouched by birds, though sometimes eaten by monkeys, until they become over-ripe, in which condition they are eagerly devoured by birds, including crows, which visit the leafless trees in winter, testing each fruit and eating those which have become soft and leaving those which have not yet reached this condition ; in this way the seeds are scattered.

Gamble notes that the leaves are attacked by the fungus *Gymnosporangium Cunninghamianum*, Barcl., whose alternate generation is on the Himalayan cypress, and that another species is also found on it, *G. clavariaeforme*, Jacq., whose alternate generation is probably on the juniper.

The growth is moderate. Gamble's specimens showed 8 rings per inch of radius, or a mean annual girth increment of 0.78 in. A cross-section 2 ft. 10 in. in girth in the silvicultural museum at Dehra Dun had 31 rings, giving a mean annual girth increment of 1.1 in.

ORDER XXV. HAMAMELIDACEAE

Genera 1. BUCKLANDIA, R. Br.; 2. PARROTIA, C. A. Meyer.

1. BUCKLANDIA, R. Br.

Bucklandia populnea, R. Br. Vern. *Pipli*, E. Him.

A tall handsome evergreen tree with cordate shining coriaceous leaves and thick fleshy stipules. Bark of poles blackish and slightly rough, that of old trees reddish brown and deeply furrowed. The bole is long but seldom entirely free from side branches, and the crown is dense and spreading ; poles grown in the open are pyramidal in shape, and often have several leading shoots. The tree reaches very large dimensions, attaining a height up to 140 to 150 ft. Mr. H. S. Gibson records a tree 22 ft. 6 in. in girth (see Fig. 186) ; the largest apparently sound stem measured by him was 17 ft. in girth.

This is one of the most valuable trees of the Darjeeling hills, with a reddish brown durable wood used for planking, flooring, door and window frames, and many other purposes. It is one of the best trees for afforestation and for the protection of hill slopes liable to landslips ; it is also an excellent soil-improver. It was at one time so extensively cut out in the Darjeeling forests that there are now very few large trees left, and the timber seldom comes on to the market ; it is, however, being extensively planted.

DISTRIBUTION AND HABITAT. The eastern Himalaya, Khasi hills, Manipur, and the hills of Martaban. In the Darjeeling hills it is found between 3,000 and 8,000 ft., but thrives best between 4,000 and 6,500 ft. The climate here is moist, the normal rainfall being about 120 to 160 in. The tree is found on various aspects ; a northerly aspect suits it best, no doubt owing to favourable conditions of soil moisture, but plantations on southerly dry slopes have succeeded well, showing that it is adaptable. It prefers a thoroughly moist sandy loam, though it does well on clayey soils, and is not exacting : it grows better in depressions than on ridges. The tree grows in mixture with other species of the Darjeeling hills, but has a great tendency to regenerate on newly exposed ground on landslips and similar places, where it often forms

pure groups ; on such places it is frequently associated with *Alnus nepalensis*, which also regenerates freely on newly exposed ground. It occurs sometimes on precipitous ground.

FLOWERING AND FRUITING. The tree produces flowers and fruits at various seasons, and one tree in flower and another in fruit may be found side by side. The fruit is a small globose capsule, in which the lower seeds are winged and fertile and the upper ones are sterile. The seeds (Fig. 189, *a*) are 0.2–0.3 in. long, compressed, angular, reddish brown, smooth, moderately hard, light, about 7,000 weighing 1 oz. The small light winged seeds are capable of being blown to a considerable distance by the wind. Good seed-years are of frequent occurrence. Although seed is obtainable at almost any time of year, Mr. J. R. P. Gent has observed that seed collected in March gives the best results, possibly because the climatic conditions in the following months are most favourable for germination and early development ; these conditions are sufficient warmth and probable showers of rain in May. Great care is necessary in collecting the seed. If collected a day or two before it is actually ripe it will not germinate, while if collection be delayed too long the seed will have escaped from the capsules. The fruits should therefore be collected when they are just commencing to open and spread in the sun to open them, the seed then being shaken out and sown at once.

GERMINATION (Fig. 189, *b-i*). Epigeous. The whitish radicle emerges from one end of the seed, the hypocotyl elongates by arching and soon straightens, carrying the cotyledons above ground. The testa is almost always carried up over the cotyledons, and frequently adheres to the end of one of them after they expand, eventually falling to the ground.

THE SEEDLING (Fig. 189).

Roots : primary root moderately long, at first thin and delicate, afterwards wiry, flexuose : lateral roots numerous, long, fibrous. **Hypocotyl** distinct from root, 0.5–0.8 in. long, terete or slightly compressed, white or pink turning green, minutely pubescent. **Cotyledons :** petiole about 0.05 in. long : lamina 0.3–0.35 in. by 0.2 in., foliaceous, somewhat fleshy, elliptical or ovate, apex rounded, entire, glabrous. **Stem** erect, terete or slightly compressed, pubescent, appearing jointed owing to the ring-like scars left by the stipules after falling. **Leaves** simple, alternate. Stipules 0.2 by 0.1 in. in young seedlings, up to 0.8 by 0.4 in. in second season, somewhat unequally elliptical, pubescent, enclosing the terminal bud, deciduous. Petiole 0.2–2 in., pubescent. Lamina 1–2.5 in. by 0.9–2 in., cordate, acuminate, entire, glabrous above, slightly pubescent beneath, venation arcuate with five prominent veins from the base. The leaves increase considerably in size, to about 4–5 in. long and broad in the second season.

The growth of the seedling for the first few years is somewhat slow. It reaches a height of only a few inches by the end of the first season, adding a few inches more by the end of the second season ; plants raised at Dehra Dun were 4–10 in. high at the end of the second season. The seedlings are capable of standing a fair amount of shade, but once established they develop much better if full light is admitted ; shade tests at Dehra Dun showed that they are killed by very dense shade. In heavy weed-growth the young plants become suppressed, but if they surmount the weeds their strong leaders penetrate through almost anything. At Dehra Dun they were found to damp



FIG. 189. *Bucklandia populnea*. Seedling.

a, seed $\times \frac{3}{2}$; *b-i*, germination stages (*b-h* $\times \frac{3}{2}$, *i* $\times \frac{1}{2}$); *j-l*, development of seedling during first season $\times \frac{1}{2}$; *m*, seedling early in second season $\times \frac{1}{2}$

off if given too much water. The seedling is sensitive to frost, but in its natural home it is usually out of danger after it reaches a height of 3 or 4 ft. At Dehra Dun seedlings in the open were killed in large numbers during the winter. The young plant is not usually considered very sensitive to drought in the Darjeeling hills, but at Dehra Dun seedlings in the open died off in large numbers during the hot weather even when watered, whereas those kept under slight shade survived.

SILVICULTURAL CHARACTERS. The tree is a shade-bearer, and also gives heavy shade; it develops best, however, with abundant overhead light, though it requires to be grown in a close crop in order to counteract its tendency to form numerous side branches. Fig. 187 shows a pole grown in a crop sufficiently dense to produce a clean bole. It does not coppice except when young, and it does not produce root-suckers. It is sensitive to frost in youth, but later it is immune in its natural home. In dry situations it is liable to suffer from prolonged drought, but in the Darjeeling hills it is seldom severely tried in this respect. It is very sensitive to fire, and although pole crops are capable of surviving light ground fires they are killed by severe fires. The young plants are sensitive to grazing; they are readily eaten by cattle and by deer, and plantations accordingly require to be fenced, particularly against the latter.

NATURAL REPRODUCTION. As already mentioned, the small light winged seeds are carried by wind to a considerable distance from the tree, and seedlings are therefore often found a long way from any seed-bearer. The tendency to regenerate in masses on newly exposed ground on landslips and similar places has already been noted: this is a characteristic of many species with small light seeds, and is due largely to the fact that such seeds are unable to reach the ground when it is covered with a mass of undergrowth or a low thick herbaceous growth of weeds and grass, while the small seedling is unable to effect contact with the mineral soil except where the latter is exposed. Natural seedlings, however, are not confined to landslips, and are found in other places where there is no heavy soil-covering and where the shade is not too dense for their development, for instance along paths, on ridges, and sometimes in the forest itself where conditions are favourable.

ARTIFICIAL REPRODUCTION. The tree has been extensively grown in plantations in the Darjeeling hills. Seed is sometimes sown broadcast on landslips, but otherwise transplanting from the nursery is the invariable rule. Pure plantations have been found to give better results than plantations where *Bucklandia* is mixed with *Michelia excelsa* and oaks. Experience has also shown the unsatisfactory results of wide spacing owing to the tendency of this species to form numerous side branches; a spacing of not more than 6 ft. by 6 ft. is now considered advisable.

The usual method adopted in the forest nurseries in the Darjeeling hills is to sow freshly collected seed in nursery beds of fine earth in March or April, the seed being lightly covered with earth. The seedlings are either pricked out 6 in. by 6 in. at the end of the first season and again transplanted 6 in. apart in lines 9 in. apart at the end of the second season, or left for two years in the seed-beds and transplanted into nursery lines 1 ft. apart in the third season. Beds containing seedlings up to two years old are protected by screens



FIG. 190. *Bucklandia populnea* plantation 5 years old. Surul, Darjeeling hills. 4300 ft. elevation.

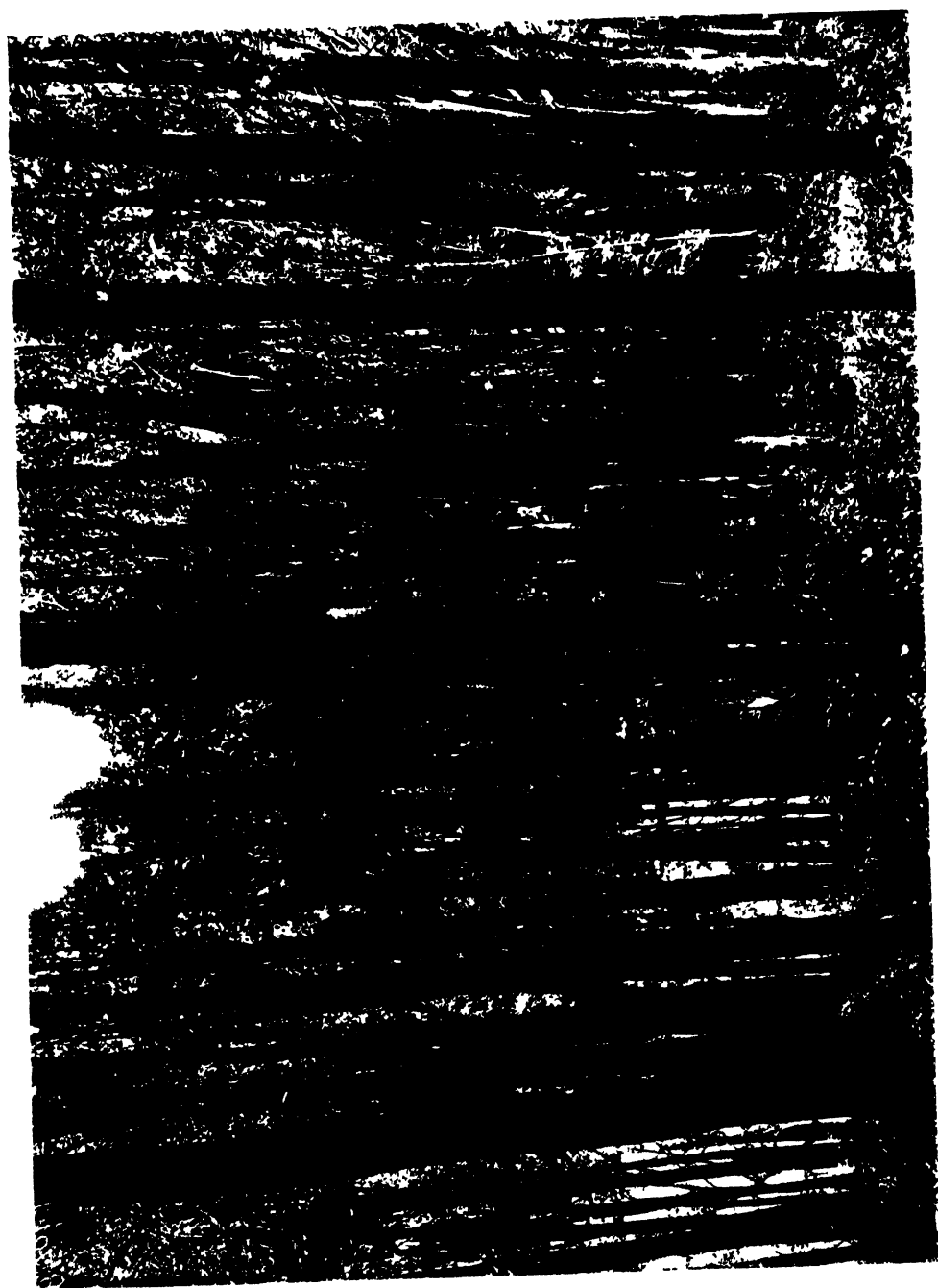


Fig. 1. The forest of plantation 38 years old below Rangrum - Darjeeling hills.

from heavy rain, from frost in the winter, and from a hot sun in the summer. The seedlings are usually kept in the nursery until four years old, by which time they are about 3 ft. high and are large enough to plant out into the forest; they can be transplanted when three years old, but they are usually somewhat small and the extra cost of cleaning makes it preferable to keep them a year longer in the nursery.

Transplanting is usually carried out in the rainy season from June till early August. A break in the rains is considered the best time, as plants pitted out in rainy weather are apt to become water-logged and to die owing to an accumulation of water in the pit. Nursery plants often have too much foliage, and this should be reduced at the time of planting to prevent excessive transpiration. Winter planting is possible, but the risk of frost damage makes rains planting preferable. In places subject to severe frost it is customary to protect the plants during the first year after transplanting, usually by means of a leafy branch stuck in the ground beside the plant and broken over it. The plantations require to be fenced against deer.

In the Mongpoo plantations of the Cinchona Department a different method is adopted. The seed is sown in March and April in well-manured seed-beds under the shelter of double bamboo mats. When about 3 in. high the seedlings are pricked out about 3 in. apart: they are kept well weeded and watered, and by the end of June in the second year are about 8 or 9 in. high. The shelter of bamboo mats is then gradually removed and the seedlings are transplanted with balls of earth, the planting holes being dug to a depth of 18 in. at least a fortnight in advance. The plants are tended carefully for the first year or so after they are put out, and when there is danger of drought the ground around their roots is covered with grass. When the ground becomes hard it is forked up all round the plants. Under this treatment the growth is fast, the plants attaining a height of 20 ft. in seven or eight years on good soil.

Fig. 190 shows a young plantation, and Figs. 188 and 191 show older plantations.

SILVICULTURAL TREATMENT. The best treatment for *Bucklandia* is to grow it in dense pure crops with sufficient side shade to prevent the formation of side branches but with abundant overhead light to promote height-growth. The tending of natural plants or crops as well as of plantations requires to be carried out with this object in view.

RATE OF GROWTH. Young plants ordinarily reach a height of 3 ft. in five years and 8 to 15 ft. in ten years. At fifteen years the height is about 15 to 25 ft., and at twenty years about 30 to 40 ft., with a girth of $1\frac{1}{2}$ to 2 ft. According to Gamble the radial growth is 6 to 7 rings per inch of radius, representing a mean annual girth increment of 0.9 to 1 in., which is fairly fast.

A plantation below Rangirum in the Darjeeling hills, shown in Fig. 191, was measured in 1917 with the following results:

Age. years.	No. of stems per acre.	Mean girth. in.	Mean height. ft.	Solid volume per acre. cub. ft.
38	220	36.2	79	4,517 (timber 2,889 cub. ft.)

A thinning carried out that year gave a total of 1,632 cub. ft., of which timber amounted to 878 cub. ft.

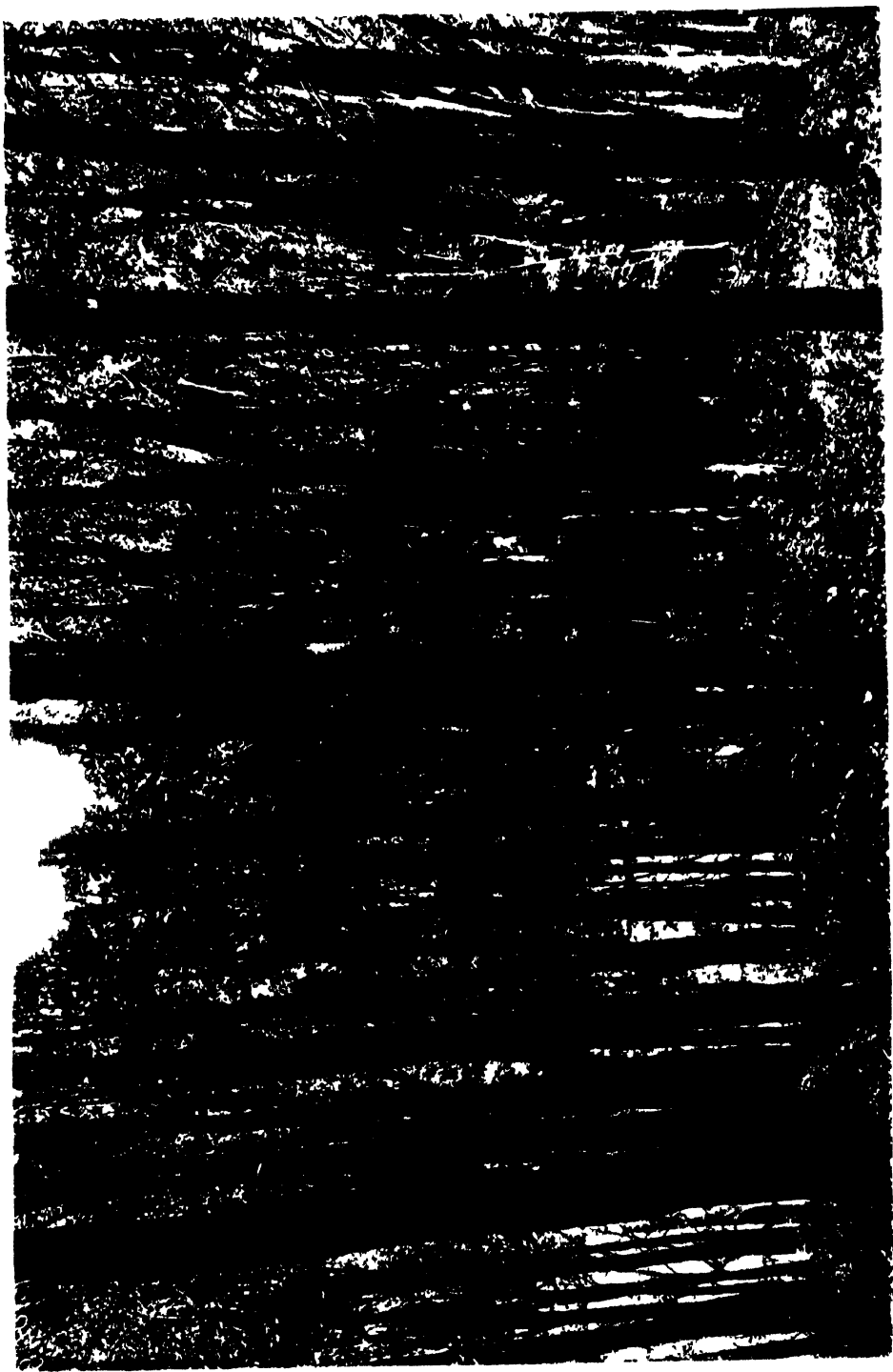


Fig. 1. Forest of plantation 38 years old below Rangum Darjeeling hills

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2. PARROTIA, C. A. Meyer.

Parrotia Jacquemontiana, Dcne. Himalayan witch-hazel. Vern. *Páser*, *kilár*, *shtar*, Punjab.

A large gregarious deciduous shrub or small tree, strongly resembling a hazel, occurring between 3,000 and 8,500 ft. in the Himalaya from the Jumna westward. It is used chiefly for wicker-work for the walls of houses and for rope-bridges, the twigs being flexible and very tough: it is also used for walking-sticks and other purposes. Silviculturally it is of importance owing to the abundance with which it springs up as an underwood in certain localities. It coppices very vigorously, stands a certain amount of shade, and forms dense masses which impede the reproduction of deodar, blue pine, and other trees. It is a good soil-improver, and if it can be kept down sufficiently to allow young deodar and pine to penetrate its cover they grow well: the only means of ensuring this seems to be to cut back the *Parrotia* repeatedly, a costly operation owing to its vigorous power of coppicing.

ORDER XXVI. RHIZOPHORACEAE

This order comprises for the most part a number of littoral species collectively known as mangroves, which, together with certain species belonging to other natural orders, make up the curious littoral forest formation known as mangrove swamp. Of non-littoral species the most important is *Carallia lucida*, Roxb.

MANGROVE SWAMP. Mangrove forest is found in littoral regions throughout the tropics, not along sandy beaches or rocky shores which are exposed to the full force of the wind and the waves, but in the estuaries of rivers, in creeks and lagoons, and on low islands where the force of these agencies is not so strong. In such places the mangrove belt occupies a strip of low-lying muddy ground, subject to inundation by ordinary tides, the strip varying in width from less than a hundred yards to several miles.

DISTRIBUTION AND SPECIES. In a classification of the mangrove formations of the world two broad but well-defined areas are distinguishable—an eastern area embracing East Africa, Asia, and the Polynesian Islands down to Australia, and a western area comprising the coasts of America and West Africa. The species in the respective areas are distinct, but the eastern area is far richer in species than the western. The most extensive and highly developed mangrove forests are found in the Malayan region, and particularly in the island of Borneo, where the configuration of the country favours the formation of mangrove swamps over large areas in the coastal regions.¹

In the Indo-Burman region the mangrove forests are distributed to a greater or less extent in suitable localities throughout the coastal regions, from the delta of the Indus in Sind southwards along the west coast of the Peninsula down to Trávancore, from the Sundarbans southwards along the east coast of the Peninsula and down the coast of Chittagong, Arakan, and Burma; also along the coast of the Andamans and adjacent islands. The mangrove forests of Arakan are estimated to cover 948 square miles, while

¹ Distribution and Utilization of the Mangrove Swamps of Malaya, F. W. Foxworthy, 1909 (Ann. Jard. Bot. Buitenzorg, 2^e sér., Suppl. III).

there are further large stretches of mangrove both north and south of Mergui along the coast and round the islands.

The natural orders and the principal species which make up the mangrove formations of the Indo-Burman region, and the localities in which they are known to occur, are given in the following tentative table :

Distribution of mangrove swamp species in the Indo-Burman region.

Natural order.	Specis.	Sind (Indus delta).	Indian Peninsula, west coast.	Indian Peninsula, east	Sunda	Chittag.	Burma	Andan
Rhizophoraceae	<i>Rhizophora mucronata</i> , Lam.	x	x	x	x	x	x	x
	<i>R. conjugata</i> , Linn.	x	x	?	?	x	x	x
	<i>Ceriops Candolleana</i> , Arn.	x	x	?	x	..	..	x
	<i>C. Roxburghiana</i> , Arn.	x	x	?	x	x	x	..
	<i>Kandelia Rheedii</i> , W. and A.	..	x	x	.	x	x	x
	<i>Bruguiera gymnorrhiza</i> , Lam.	x	x	x	x	x	x	x
	<i>B. eriopetala</i> , W. and A.	..	x ¹	..	..	..	..	..
	<i>B. caryophylloides</i> , Bl.	..	x ²	..	..	..	x ³	..
	<i>B. parviflora</i> , W. and A.	..	..	..	x	..	x ³	x
Meliaceae	<i>Carapa obovata</i> , Bl.	..	x	?	x	x	x	x
	<i>C. moluccensis</i> , Lam.	..	..	..	x	..	..	x
Leguminosae	<i>Cynometra ramiflora</i> , Linn.	..	x	x	x	x	x	x
Combretaceae	<i>Lumnitzera racemosa</i> , Willd.	..	x	?	x	x	x	x
	<i>L. coccinea</i> , W. and A.	..	..	..	..	..	x ⁴	x ⁵
Lythraceae	<i>Sonneratia acida</i> , Linn. f.	x	x	x	x	x	x	x
	<i>S. apetala</i> , Ham.	..	x	?	x	x	x	..
	<i>S. alba</i> , Smith	..	x	..	..	..	x ⁴	x
	<i>S. Griffithii</i> , Kurz	..	..	..	..	..	x	..
Rubiaceae	<i>Scyphophora hydrophyllacea</i> , Gaertn.	..	..	x	..	..	..	x
Myrsinaceae	<i>Aegiceras majus</i> , Gaertn.	x	x	x	x	x	x	x
Acanthaceae	<i>Acanthus ilicifolius</i> , Linn.	..	x	?	x	x	x	..
Verbenaceae	<i>Avicennia officinalis</i> , Linn.	..	x	x	x	x	x	x
Euphorbiaceae	<i>Excaecaria Agallocha</i> , Linn.	..	x	x	x	x	x	x
Palmeae	<i>Nipa fruticans</i> , Wurm.	..	..	..	x	x	x	x
	<i>Phoenix paludosa</i> , Roxb.	..	..	..	x	x	x	x

¹ Malabar and Travancore.

² Travancore.

³ Tenasserim.

⁴ Mergui.

⁵ Nicobars.

Although the species mentioned in this table occur in the mangrove swamps, some of them are by no means confined to them, and may extend to the drier ground farther inland.

CHARACTERISTICS OF MANGROVE SWAMPS. Mangrove swamps are formed on the silt which is washed down by rivers and creeks, and which, subject to occasional erosion, gradually spreads seawards, the mangrove spreading with it and helping, by means of its dense growth and mass of roots, to hold up the silt and form new land. As the silt accumulates the ground gradually rises and becomes drier, and an entirely new formation replaces the mangrove; this formation occurs on land which is inundated only by spring tides, and is commonly known as tidal forest. The most important Indian species of the tidal forest is the *sundri* (*Heritiera Fomes*). Although some of the species of the mangrove swamp extend into this forest many new species appear. The mangrove formation extends up rivers sometimes for miles, and is usually intersected by numerous creeks, which are often dry at low tide but can be

ascended by boats at high tide. The ground is a soft mud which is often knee-deep, but can be traversed on foot, with some difficulty and discomfort, at low tide. On the seaward side there is usually a stretch of shallow water into which the mangrove is spreading, and approach by boat from that side is often difficult or impossible; the mangrove swamp can, however, be penetrated by boat and often by launch, along the creeks.

ROOT-SYSTEM. The root-system of the mangroves is highly specialized. In the case of *Rhizophora* the lower part of the stem dies early, and the stem is supported by numerous stilt-like roots which raise it above the mud, while aerial roots are sent down from the stem and branches and anchor themselves in the ground. These stilt-roots are covered by water at high tide and exposed at low tide. *Rhizophora* is usually characteristic of the outer edge of the mangrove swamp, and the mass of stilt-roots is a conspicuous sight on approaching the shore. These peculiar stilt-roots are not conspicuously developed in other species of the mangrove formation except in *Acanthus ilicifolius*, a thistle-like herbaceous or shrubby plant with prickly leaves, which sometimes forms a dense undergrowth. In other species the roots are superficial, twisting about on the surface of the mud, sometimes ribbon-shaped as in *Carapa obovata*, sometimes bending out of the mud in the form of knees (i. e. knee-rooted), as in *Bruguiera*, *Kandelia*, and *Lumnitzera*. Some species produce pneumatophores which rise out of the mud from the superficial roots and resemble inverted tent-pegs. The ribbon-roots, knee-roots, and vertical pneumatophores, some mere knobs or finger-like outgrowths and others, as in *Sonneratia apetala* and *Avicennia officinalis*, of considerable size, are all adaptations for supplying the roots with oxygen, and are covered with lenticels or exhibit other devices for breathing purposes, such as the shedding of cortex.

LEAF-STRUCTURE. The habitat of the mangroves, namely swampy ground impregnated with salt, is a physiologically dry one, and the leaves of the trees therefore possess a marked xerophilous structure, 'with a thick cuticle, large mucilage-cells, protected stomata, and especially a large-celled thin-walled, aqueous tissue, the dimensions of which increase with the age of the leaf and with the corresponding rise in the amount of salt contained. Old leaves serve essentially as water-reservoirs for the younger leaves' (Schimper).

GERMINATION. One of the most interesting characteristics of the Rhizophoraceae is that they exhibit vivipary. The fruit is indehiscent, and there is no resting stage for the embryo as in the case of normal seeds. As soon as the fruit is fully developed the embryo commences to grow inside it; the radicle soon pierces its apex, and the hypocotyl elongates and protrudes, hanging vertically from the fruit. After it has reached a length varying from a few inches in some species to $1\frac{1}{2}$ –2 ft. or more in the case of *Rhizophora mucronata*, the embryo plant falls, leaving the cotyledons inside the fruit, which remains on the tree. The lower part of the hypocotyl is thicker than the upper part, and in some cases the lower extremity (radicle) comes to a sharp point; when the embryo falls into the mud, therefore, it becomes firmly planted in a more or less vertical position. Within a short time of falling the young seedling produces rootlets from its lower extremity, thus further establishing itself, and before long the first pair of foliage leaves are produced at its apex. The embryos are buoyant, and if they do not obtain an immediate footing under

the parent tree, or are uprooted, they are carried by water and find a resting-place in the mud, eventually establishing themselves in an upright position through the positively geotropic nature of the lower extremity and the negatively geotropic nature of the upper extremity (shoot).

It will thus be seen that the term sowing or dibbling of mangrove seed is strictly speaking incorrect ; it is the embryo or young seedling which is planted in the ground.

In the other species of the mangrove formation vivipary is also exhibited by *Aegiceras majus* and *Avicennia officinalis*, and although it does not occur in other species, the embryos of some, particularly those of *Acanthus ilicifolius*, are always further developed than is usual in inland plants.

LOCAL OCCURRENCE OF SPECIES. The requirements of the various species of the mangrove swamp differ to some extent, particularly as regards water, and their local distribution is influenced accordingly. The species of *Rhizophora* grow typically on the outer and seaward fringe of the swamp, where the water is most salty and exposure to wind and wave is greatest. *R. mucronata* can apparently live in pure salt water, for Schimper notes that he has seen it thriving on the rocky ground of the coral islands of the Java Sea, where there is no fresh water.¹ *Ceriops* spp. grow well out in the swamp. *Bruguiera gymnorhiza* and *B. parviflora* require a greater admixture of fresh water, and grow farther inland behind the *Rhizophora*, the first named, the largest of the mangroves, overtopping the surrounding vegetation. *Sonneratia* spp. and *Avicennia officinalis* not only grow in deep mud in the mangrove swamp, but also extend some distance inland into the tidal forest, and are found in the upper stretches of the tidal streams. *Carapa* spp. occur mainly in the drier parts of the swamp, often near or just beyond high-water mark, and extend into the tidal forest in areas remote from the mangrove swamp. *Avicennia officinalis* may occur near the outer edge of the swamp or at some distance up tidal streams on wet ground : it sometimes comes up in abundance on cleared areas. *Acanthus ilicifolius* sometimes forms a rather dense prickly undergrowth, growing near the sea. The palm *Nipa fruticans* is at times very abundant, not only in the mangrove swamp but also in the drier tidal forest beyond high tide, forming fringes along the banks of creeks.

Interference with the free flow of tidal water and of fresh water from the landward side may alter the character of or destroy the normal vegetation of the mangrove swamp. Thus at Port Blair in the Andamans attempted reclamation by means of embankments has rendered large areas unfit for the growth of mangroves, and marshy blanks have resulted.

METHOD OF WORKING MANGROVE FOREST. The working of mangrove forest is carried out under different methods. The coppicing and pollarding capacity of the different species have not been studied in detail. In unregulated fellings rough pollarding is often carried out. Working plans for mangrove areas in the Madras Presidency prescribe coppice fellings under a rotation of five years in one case and ten years in another. Larger trees which have been pollarded are said to have thrown out vigorous pollard-shoots. In the Andamans a considerable area has been clear-felled and replanted. In the Federated Malay States the selection system is in operation, the felling cycle being twenty

¹ Plant Geography, p. 396.

years, and the minimum felling limit being a girth of 1 ft. at $4\frac{1}{2}$ ft. from ground-level. The system is said to be difficult to control, and when, as sometimes happens, the crop consists mainly of stems 1 ft. in girth and over, clearings may result, and artificial reproduction has to be resorted to.¹ The retention of seed-bearers in such places should help to regenerate the blanks naturally.

ARTIFICIAL REPRODUCTION. Artificial reproduction is a simple matter, the embryos being collected off the ground after falling and stuck vertically in the mud. In the Andamans mangrove plantations were commenced in 1897, the species employed being *Rhizophora mucronata*, *R. conjugata*, *Bruguiera gymnorhiza*, *B. parviflora*, *Kandelia Rheedii*, and *Ceriops Candolleana*. These plantations were extended until 1908, when the total area amounted to 685 acres, the cost of creation being Rs. 5,368 or slightly under Rs. 8 per acre. The original spacing is said to have been 3 ft. by 3 ft., which proved to be excessively close, and some years later alternate rows were cut out, as well as alternate saplings in each row, leaving a spacing of 6 ft. by 6 ft. These plantations have suffered much from the erection of bunds already referred to, whereby the flow of fresh and tidal water was interfered with.

In Burma in 1908 five acres in the Zapathwe fuel reserve in the Hanthawaddy district were cleared of all undergrowth and species of little value and planted 4 ft. by 4 ft. at the end of October with *Rhizophora mucronata* (2 acres), *R. conjugata* (1 acre), and *Kandelia Rheedii* (2 acres). The overhead clearance caused early drying of the mud, while hog-deer ate off the main shoots, with the result that only about 30 per cent. of the seedlings survived until the following May, and these were in poor condition. Similar experiments with *Rhizophora mucronata* and *R. conjugata* in the Mingalun fuel reserve in the same district gave better results, about 30 per cent. of the former species and 40 per cent. of the latter being in good condition, with a height of about $2\frac{1}{2}$ ft., by the following May. In the Federated Malay States the embryos are usually dibbled in 4 ft. by 4 ft. or 6 ft. by 4 ft., and the percentage of survivals is high, almost the only danger being from crabs, which eat through the stem at its base.

RATE OF GROWTH AND OUT-TURN. The rate of growth of mangroves is said to be slow, but actual statistics are not available except in the case of the Andamans plantations, where *Rhizophora mucronata* and *Bruguiera gymnorhiza* attained a height of 30–35 ft. and a girth of 9–12 in. in fifteen years. Sample plots in Arakan gave an average yield per acre of 3 tons of bark and 25 tons of wood in clear-felled coupes.

Genera 1. RHIZOPHORA, Linn.; 2. CERIOPS, Arn.; 3. KANDELIA, W. and A.; 4. BRUGUIERA, Lam.; 5. CARALLIA, Roxb.

1. RHIZOPHORA, Linn.

Species 1. *R. mucronata*, Lam.; 2. *R. conjugata*, Linn.

1. *Rhizophora mucronata*, Lam. Vern. *Bhara*, Beng.; *Kandal*, Mar.; *Kamo*, Sind; *Uppu poma*, Tel.; *Pyu*, Burm.

A small to moderate-sized evergreen tree with elliptical mucronate leaves 4–7 in. long, the young branches thick and prominently marked with the scars of fallen leaves and stipules. Bark fairly smooth, brown. This tree produces

¹ The Mangrove Forests of the West Coast, F.M.S., J. P. Mead, 1912.

characteristic stilt-roots, the lower portion of the stem dying early and the tree remaining propped up on numerous roots which are submerged at high tide and stand out of the mud at low tide. Aerial roots are also produced from the branches, these fixing themselves in the mud. This tree is the one most commonly found on the outer fringes of the mangrove swamp where the water is decidedly salty, and the action of the tides and waves is most strongly felt: its peculiar root-system therefore is of special advantage in forming an anchorage to withstand this action.

The conspicuous white flowers appear in the hot season and rainy season, and the fruits ripen in the rainy season. The fruit (Fig. 192, *a*) is 1.5–2 in. long, conical-ovoid, pendulous, coriaceous, rough, dark brown. The hypocotyl (Fig. 192, *b–d*), which emerges through the apex of the fruit, is sharp pointed and rough with lenticels. Before dropping it attains a considerable length, ordinarily up to 1½–2 ft., but sometimes longer, and the seedling is thus able to establish itself in water of some little depth, the sharp point of the hypocotyl penetrating the mud and the young plant being kept upright while the roots are rapidly developed and the first pair of foliage leaves appear at the apex of the shoot. Seedlings which have established themselves in this way may often be found in quantity in the mud and shallow water round the parent trees. The tree commences to produce fruits at an early age.

The sapwood is light red and the heartwood dark red, hard, but splits in seasoning. It is a good fuel. The bark is used for tanning.

2. *Rhizophora conjugata*, Linn. Vern. *Pyu-ma*, Burm.

A tree somewhat smaller than, but with habits similar to those of the last species, with which it is commonly associated. The leaves are narrower and darker than in *R. mucronata*; it can be most easily distinguished by the calyx-lobes, which are pale yellow within. The fruit is about 1 in. long; the hypocotyl is smaller than in *R. mucronata*, up to about 1 ft. long.

2. CERIOPS. Arnott.

Species 1. *C. Candolleana*, Arn.; 2. *C. Roxburghiana*, Arn.

1. *Ceriops Candolleana*, Arn. Vern. *Goran*. Beng.; *Chauri*, Sind.

2. *Ceriops Roxburghiana*, Arn. Vern. *Goran*, Beng.; *Guttia*, Chittagong; *Kabaing*, Burm.

Small evergreen trees resembling each other in appearance and habit, and distinguished mainly by the inflorescence, which is more compact in the latter than in the former. The bark of both species contains a great deal of red colouring matter. The stem is not supported by stilt-roots as in *Rhizophora*, but aerial roots are sent down from the branches, and small or inconspicuous pneumatophores are produced. The fruit, which is about 1 in. long, ripens in August–September, and the hypocotyl when it falls is 4–6 in. long by 0.25–0.35 in. in diameter, longitudinally grooved and ribbed, tapering upwards: about 120–150 of the embryos weigh 1 lb. Fig. 192, *e–g*, shows germination and the development of the young seedling.

Brandis gives the respective distribution of the two species as follows:

C. Candolleana. Tidal forests of Sind, the Indian Peninsula, Bengal, and the Andamans. Sea-coast of tropical Asia, Africa, and Australia.



FIG. 192. Rhizophoraceae. Germination.

Rhizophora mucronata $\times \frac{1}{4}$; a, fruit; b, fruit with radicle protruding; c, fruit with embryo (hypocotyl) half grown; d, embryo after falling from fruit.

Ceriops Candolleana $\times \frac{1}{4}$; e, fruit with protruding hypocotyl fully developed; f, embryo detached from fruit; g, h, development of young seedling.

C. Roxburghiana. Sundarbans, coast of Burma, Malay Peninsula and Archipelago.

Both are indiscriminately known in the Sundarbans as *goran*, and are in great demand for fuel and house-posts. The *goran* is often gregarious, forming nearly pure forests in many places; it is also found in mixture with various other species. In Chittagong, *Cerrops* is worked as coppice on a rotation of eight years for the production of small fuel and of bark, the latter being sold to fishermen for tanning their nets. In the Malay region the bark is considered superior to that of any other mangrove for cutch making: it is also used for dyeing a red colour.

3. KANDELIA, Wight and Arn.

Kandelia Rheedii, W. and A. Vern. *Goria*, Beng.; *Madama*, Burm.

An evergreen shrub or small tree with spongy reddish brown flaky bark, elliptical oblong leaves 3–5 in. long, and white flowers. Fruits ovoid, 0.5–1 in. long, encircled by the calyx lobes; hypocotyl up to 15 in. long. This mangrove is not as a rule so common as most of the others; it occurs usually on the banks of tidal rivers some little distance inland, and not so much near the sea-face. The wood is soft, and is used only for fuel and charcoal.

4. BRUGUIERA, Lam.

Species 1. *B. gymnorhiza*, Lam.; 2. *B. eriopetala*, W. and A.; 3. *B. caryophylloides*, Bl.; 4. *B. parviflora*, W. and A.

1. *Bruguiera gymnorhiza*, Lam. Vern. *Kankra*, Beng.; *Kandal*, Mal.

This, the largest of the mangroves, is an evergreen tree attaining under favourable conditions a height of 80 ft., though in India a height of 30–40 ft. is more usual. In Malaya it is said to reach a height up to 100 ft. and a girth up to 5 or 6 ft. Bark rough, dark, with large corky lenticular patches. Flowers large, solitary, orange or red. Fruit 0.7–1 in. long, enclosed in the calyx tube and crowned by the 12–14 red calyx lobes. The hypocotyl usually grows to 6–12 in. in length before dropping, but may attain a length of 2 ft. The flowers and fruits are produced from June to October.

This tree is a common one in the mangrove forests of the Indian region, being associated with the two species of *Rhizophora* and occurring as a rule immediately behind them. Unlike these, however, it is not supported on stilt-roots, but produces knee-roots along the surface of the ground.

Bourdillon says it is very common on the backwaters about Quilon, forming with the two species of *Rhizophora* the majority of the mangroves seen there. Talbot says it is equally common with *Rhizophora* in the North Kanara mangrove formations, and Prain says it is the chief constituent of the mangrove jungles in the Cocos Islands.

The wood is reddish brown, very hard, used for beams, posts, planks, and firewood; it is said to be difficult to split. The bark is sometimes used for tanning.

2. *Bruguiera eriopetala*, W. and A.

A tree strongly resembling the last species, but smaller, with large, solitary, yellow flowers.



FIG. 192. Rhizophoraceae. Germination.

Rhizophora mucronata $\times \frac{1}{2}$; a, fruit; b, fruit with radicle protruding; c, fruit with embryo (hypocotyl) half grown; d, embryo after falling from fruit.

Ceriops Candolleana $\times \frac{1}{2}$; e, fruit with protruding hypocotyl fully developed; f, embryo detached from fruit; g, h, development of young seedling.

C. Roxburghiana. Sundarbans, coast of Burma, Malay Peninsula and Archipelago.

Both are indiscriminately known in the Sundarbans as *goran*, and are in great demand for fuel and house-posts. The *goran* is often gregarious, forming nearly pure forests in many places; it is also found in mixture with various other species. In Chittagong, *Cerrops* is worked as coppice on a rotation of eight years for the production of small fuel and of bark, the latter being sold to fishermen for tanning their nets. In the Malay region the bark is considered superior to that of any other mangrove for cutch making: it is also used for dyeing a red colour.

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Kandelia Rheedii, W. and A. Vern. *Goria*, Beng.; *Madama*, Burm.

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The wood is reddish brown, very hard, used for beams, posts, planks, and firewood; it is said to be difficult to split. The bark is sometimes used for tanning.

2. *Bruguiera eriopetala*, W. and A.

A tree strongly resembling the last species, but smaller, with large, solitary, yellow flowers.

3. *Bruguiera caryophylloides*, Bl., including *B. malabarica*, Arn.

This is the smallest and probably the rarest species of the genus. The bark is thin, brown, the foliage light green, the leaves thinly coriaceous, and the flowers small, white, in 2- to 3-flowered cymes. The fruit is yellow, about 0.5 in. long, and the hypocotyl reaches a length of about 6-8 in. before falling. Flowering and fruiting take place in the rainy season.

4. *Bruguiera parviflora*, W. and A.

A small tree, widely distributed in the mangrove formations of the Eastern Hemisphere, and often very common, sometimes forming pure crops in the middle of the mangrove swamp. In some localities it attains a fair height, but it is always of small girth: in the Indian region it is a small tree or a mere shrub. The foliage is yellowish green, paler than in the previous species. The fruit is about 1 in. long, enclosed in the enlarged calyx: the flowers and fruits appear in the rainy season. The hypocotyl is furrowed, truncate, and reaches a length of only 4-5 in. before falling. The tree grows on drier ground than *Rhizophora*, chiefly away from the banks of streams, and often reproduces in great profusion.

5. CARALLIA, Roxb.

Carallia lucida, Roxb. Syn. *C. integerrima*, DC. Vern. *Shengali*, *panasi*, Mar.; *Andi*, *andamuria*, Kan.; *Karalli*, Tel.; *Thekera-máhi*, Ass.; *Maniawga*, Burm.

A moderate-sized to large handsome evergreen tree with a dense crown of shining opposite leathery elliptical leaves, and pronounced opposite branching. Bark moderately thick, the outer dead bark corky, furrowed, dark grey outside, pink when cut, the inner living cortex pale greenish yellow or pinkish when newly cut, turning orange brown on exposure. There are numerous small corky excrescences on comparatively small-sized twigs of the previous year's growth; the new twigs are green. The numerous broad medullary rays are conspicuous as vertical streaks on the outer surface of the sapwood and on the inner surface of the cortex when the latter is stripped off. Sometimes the tree produces aerial roots, showing its relationship to the mangroves. The tree is at times mistaken for a *Garcinia*, and vice versa, but the pink corky bark is a distinctive feature, while the cut cortex of *Garcinia* spp. exudes a yellow gum-resin which is not present in that of *Carallia*. In Burma the tree reaches a height of 50-80 ft., with a girth of 6 or 7 ft. In the Indian Peninsula it is smaller.

The wood is hard and very ornamental if cut radially, the large medullary rays giving it the appearance of good oak; the heartwood is red to chestnut-brown. The wood is suitable for panelling, furniture, picture-frames, and similar purposes.

DISTRIBUTION AND HABITAT. The tree is found in limited quantity in damp evergreen and swamp forests in the sub-Himalayan tract as far west as Dehra Dun; it is very scarce in the west but commoner in the east. It occurs in Bengal, ascending to 4,000 ft. in Sikkim, Assam, Chittagong, Chota Nagpur along streams and ravines in Singhbhum (Haines), Orissa and the Circars, the Central Provinces in South Chanda along flowing streams in Ahiri and

Sironcha ranges (Haines), Western Ghats, Burma, chiefly in the moister parts of Pegu and Tenasserim : also in Ceylon, China, the Malay Peninsula and islands south to Australia. It is nowhere abundant, and is typical of moist localities, occurring in evergreen and semi-evergreen forests and along streams and moist shady ravines. In the Dehra Dun valley it is a constituent of true swamp forest, where it is associated with *Diospyros Embryopteris*, *Putranjiva Roxburghii*, *Eugenia Jambolana*, *Ficus glomerata*, *Pterospermum acerifolium*, *Cedrela Toona*, *Bischoffia javanica*, *Albizia procera*, *Trewia nudiflora*, and *Calamus tenuis*. In the Bengal Duars it occurs in moist evergreen and semi-evergreen forest associated with *Dillenia indica*, *Michelia*, *Amoora*, *Dysoxylum*, *Meliosma*, *Turpinia*, *Eugenia* spp., *Elaeocarpus* spp., *Garcinia* spp., and several Lauraceae.

Bourdillon says it is common in all the evergreen forests of Travancore up to 4,000 ft. Talbot says it is found throughout the tropical rain forests of the Konkan and North Kanara. In Burma Kurz, in his Preliminary Report, mentions that it is frequent in Pegu and Tenasserim up to 4,000 ft. on metamorphic rocks, sandstones, and permeable laterite, in evergreen tropical and upper mixed forest ; it occurs also in the lower mixed forest where it verges on evergreen forest.

In its natural habitat the absolute maximum shade temperature varies from 95° to 110° F., the absolute minimum from 33° to 65° F., and the normal rainfall from 50 to 200 in. or more.

FLOWERING AND FRUITING. The small flowers with white petals, in trichotomous cymes, appear from December to March, and the fruits ripen about May-June. The fruit is globose, fleshy, 1-seeded, coriaceous. The seed is 0.2-0.3 in. in diameter, compressed, shaped like a crescent in which the horns are curled round to form an almost complete circle, reddish brown, somewhat rough, with a fairly thick hard testa and a copious white albumen : 840-980 seeds weigh 1 oz. (samples from Burma). The seed is perishable, and while on the ground is very liable to rot and to be attacked by insects. It is difficult to explain the scattered distribution of the tree otherwise than by the dissemination of the seeds by bird agency.

GERMINATION. Epigeous. The testa splits round the edge, the radicle emerging through the opening so caused. The hypocotyl elongates by arching, raising the cotyledons above ground ; the ends of the cotyledons remain enclosed in the albumen of the seed for some little time before falling.

THE SEEDLING. Seedlings cultivated at Dehra Dun showed slow development during the first two seasons, reaching a height of 1½-2 in. by the end of the first season and 5-14 in. by the end of the second. In the earlier stages the young plants suffered much from the attacks of crickets. During the third and subsequent seasons growth was more vigorous, the height being 3 ft. 11 in. at the end of the third season, and 7 ft. 8 in., with a basal girth of 10½ in., at the end of the fifth season. The young plants were found to grow best under slight shade on ground kept well watered but loose. They proved sensitive to drought, but were not so frost-tender as might be expected from a tropical evergreen species.

Seedlings at Dehra Dun had two to three pairs of leaves by the end of the first season, the cotyledons persisting until the end of the season. Side

branches commenced to form in the second season, and from the third season onwards the branching was vigorous, with copious foliage. The following characters apply to the young plant :

Young stems bright green, somewhat flattened, with a longitudinal ridge up the centre of each flat side ; nodes swollen. Leaves opposite, lanceolate, finely serrulate, coriaceous, glabrous, shining, darker above than below, up to 5.5 in. by 1.5 in. by the end of the second season ; petiole 0.2–0.4 in. long. Young leaves very shiny, lighter green than the older ones, involute in the bud, with small acuminate interpetiolar stipules between them which quickly enlarge to 0.5–0.6 in. in length and fall, leaving well-marked brown scars extending across the shoot from base to base of the petioles.

The serrulate leaves of young plants are interesting. In the older plants they are entire, or serrulate above the middle ; in the forest young trees up to 6 or 7 ft. high or more have been noticed with all the leaves serrulate throughout.

SILVICULTURAL CHARACTERS. The tree is a shade-bearer. It coppices well and reproduces freely from root-suckers, which are sometimes produced in quantity on swampy ground. Frost does not ordinarily occur within its habitat except in the extreme north ; in the abnormal frost of 1905 it suffered severely in the Dehra Dun valley, where one tree was noticed to have been killed right down, but next year it shot up vigorously from the base. It is exacting as to soil, being found only on rich deep moist soil.

ARTIFICIAL REPRODUCTION. Experiments at Dehra Dun have shown that owing to the large percentage of failure in the seed direct sowings cannot be relied on. Transplanting, however, is easy. The seed should be sown quite fresh in drills in fairly rich but porous soil about May–June, the beds being kept well weeded and watered, and sheltered from the sun in hot weather. The plants are ready for transplanting in the rainy season when two years old.

This tree can also be grown successfully from cuttings, which should be kept in the nursery and watered and shaded until well rooted.

ORDER XXVII. COMBRETACEAE

This order is one of great importance in Indian forestry, containing as it does several trees of considerable economic as well as silvicultural importance belonging to the genera *Terminalia* and *Anogeissus*. It also contains several climbers or scrambling shrubs of the genera *Combretum*, *Quisqualis*, and *Calycopteris*. Of these *Combretum decandrum*, Roxb., conspicuous by the large white bracts of the inflorescence, is a particularly noxious climber. It is common in parts of the sub-Himalayan tract, for example on the hill slopes round Kalsi on the Jumna, in Assam, Chittagong, Burma, Chota Nagpur, and in parts of the Indian Peninsula. It forms dense masses, suppressing young seedling and coppice growth and climbing into the crowns of trees. It is very difficult to deal with, as it grows rapidly and luxuriantly after cutting, and reproduces freely from seed, quantities of young seedlings appearing in the rainy season.

Genera 1. *TERMINALIA*, Linn. ; 2. *ANOGEISSUS*, Wall. ; 3. *LUMNITZERA*, Willd.

1. TERMINALIA, Linn.

This genus is of great importance both silviculturally and economically ; it comprises ten Indian species, all trees, some of which reach large dimensions. The climatic and other requirements of the species vary considerably, *T. Oliveri* being confined to the driest parts of Burma, while others such as *T. myriocarpa*, *T. paniculata*, *T. bialata*, and *T. Catappa* are characteristic of the moister regions, the last named being essentially a littoral species. *T. tomentosa*, *T. Chebula*, and *T. belerica* are very widely distributed, while *T. Arjuna* is peculiarly restricted to the banks of streams, where, however, it is often abundant within its region.

The fruits vary. They are drupaceous in *T. belerica*, *T. Chebula*, and *T. Catappa*, ordinarily 5-winged in *T. tomentosa*, *T. Arjuna*, and *T. Oliveri*, unequally 3-winged in *T. paniculata* and *T. myriocarpa*, and broadly 2-winged in *T. bialata*. The germinative power of the seed is variable. In *T. Chebula* it is poor, in *T. belerica* usually good, while in the other important species it is more variable but often indifferent. Germination is hypogeous in *T. belerica* and epigeous in *T. tomentosa*, *T. Arjuna*, *T. Chebula*, and *T. myriocarpa*. The straggling habit of the young plant is a peculiar feature in certain species, notably *T. tomentosa*, *T. Arjuna*, and *T. myriocarpa* ; young plants of *T. belerica* are erect.

Species 1. *T. belerica*, Roxb. ; 2. *T. Chebula*, Retz. ; 3. *T. tomentosa*, W. and A. ; 4. *T. Arjuna*, Bedd. ; 5. *T. myriocarpa*, Heurck and Muell. Arg. ; 6. *T. Catappa*, Linn. ; 7. *T. paniculata*, Roth ; 8. *T. bialata*, Steud. ; 9. *T. Oliveri*, Brandis.

1. *Terminalia belerica*, Roxb. Vern. *Bahera*, Hind. ; *Tare*, Kan. ; *Goting, bherda*, Mar. ; *Tani*, Tam. ; *Tandi*, Tel. ; *Thitsein*, Burm. (Fig. 195.)

A large deciduous tree, attaining a height of 120 ft. and a girth of 10 ft. or more, usually with a straight tall bole ; large trees are often buttressed at the base. Bark bluish or ashy grey, with numerous fine longitudinal cracks, yellow inside. Leaves broadly elliptical, 4–8 in. long, clustered at the ends of the branchlets. Wood yellowish grey, hard, not durable, but lasts fairly well under water, used for planking, packing-cases, boats, and other purposes. The fruits are used for tanning, but are inferior to those of *T. Chebula*.

DISTRIBUTION AND HABITAT. The tree is found in deciduous forests throughout the greater part of India and Burma, but not in arid regions. It is a common associate of the sal, the teak, and other important trees, occurring more or less scattered and not gregariously. In the Indian Peninsula it occurs most frequently in moist valleys. In Burma it is fairly common in deciduous forests both of the upper and of the lower mixed types, with or without teak.

In its natural habitat the absolute maximum shade temperature varies from 97° to 115° F., the absolute minimum from 30° to 60° F., and the normal rainfall from 40 to 120 in. or more.

LEAF-SHEDDING, FLOWERING, AND FRUITING. In northern India the leaves commence falling in some cases as early as November, some trees being almost leafless by the end of that month, while others may be in full leaf till the end of January. The trees remain leafless until March to May, when the new foliage appears. The spikes of small greenish white flowers appear in

April-May with the young leaves ; they have a strong honey-like smell, which is almost overpowering at times. The fruits (Fig. 193, *a*) ripen from November to February and fall during the cold and hot seasons. The fruit is a somewhat dry fleshy drupe 1-1.5 in. long, ovoid, pyriform, ellipsoidal or globose, grey velvety tomentose, with a hard thick-walled woody light yellow putamen 0.7-1.1 in. long (Fig. 193, *b*). The fruits are greedily eaten by monkeys, squirrels, pigs, deer, goats, and other animals, and are never allowed to lie long on the ground before being stripped of their fleshy covering : during the cold and hot seasons small clusters of the light yellowish fruit-stones may be found lying about the forest disgorged by deer in rumination. During the cold season the trees may often be seen with numerous withering branchlets, broken by monkeys in picking the fruits. The partiality of animals for the flesh of the ripe fruits is an assistance to the spread of the seed. On the other hand, much of the fruit crop is rendered ineffective by insects and animals. The immature fruits are attacked by insects during the rainy season, and may fall to the ground. The hard nuts of the fruits are very largely bored into by insects while lying on the ground, and the whole crop may be destroyed in this way. The nuts are also frequently broken open, for the sake of the kernel inside, by squirrels, pigs, and other animals, and in some localities it is rare to find a single sound nut on the ground by the beginning of the rainy season.

The germinative power of the seed is better than that of most species of this genus, and much better than that of *T. Chebula*. Tests carried out at Dehra Dun showed a fertility of 86-100 per cent. for fresh seed and 5-40 per cent. for seed kept one year.

GERMINATION (Fig. 193, *c-e*). Hypogeous, thus differing from that of the other species under consideration. The hard putamen splits into two halves, and the radicle emerges, a strong taproot soon establishing itself. Meanwhile the cotyledonary petioles elongate, curving in the process and separating sufficiently to enable the young shoot to issue from between them. The cotyledons and the remnants of the putamen remain in or on the ground.

THE SEEDLING (Fig. 193).

Roots : primary root long, thick, terete, tapering, light brown : lateral roots moderate in number and length, fibrous, distributed down main root. **Hypocotyl** not very distinct, 0.2-0.3 in. long, subterranean. **Cotyledons** : petiole 0.4 in. long, thick, fleshy, flattened, curved to side of stem : lamina 0.6-0.8 in. by 0.5-0.6 in., thick, fleshy, broadly ovate or nearly orbicular, auricled by a basal prolongation, convolute and remaining some time within the nut. **Stem** erect, terete, green, pubescent ; internodes 0.4-1.2 in. long. **Leaves** simple, exstipulate, first pair opposite, sub-opposite or alternate, subsequent leaves alternate, earlier leaves small, subsequent leaves increasing rapidly in size. Petiole 0.1-0.3 in. long. Lamina 0.9-5 in. by 0.5-3 in., elliptical or obovate, acute, base acute or tapering, entire, glabrous above, sparsely pubescent on veins beneath, venation arched reticulate.

The growth of the seedling during the first season is only moderate, a height of about 5-8 in. being ordinarily attained. Subsequently the development is more rapid, particularly if the plants are regularly weeded, for although they are capable of making their way through weeds their development is considerably impeded in the process. The young plants do not assume the



FIG. 193. *Terminalia beloua* SEEDLING $\times \frac{7}{8}$

a—Fruit b Endocarp c e Germination stages f g Development of seedling during first season

straggling habit of some *Terminalia* species, but grow erect, producing strong side branches from the second year. A long stout taproot is formed, and develops considerably in the second year; plants only one year old, that is in the second season, have been dug up and found to have thick taproots as much as $3\frac{1}{2}$ ft. long.

The seedlings stand fairly dense shade during the first year or two, but very heavy shade suppresses and kills them afterwards. Frost often affects the leaves, but ordinary frosts do not kill back the seedlings, particularly in grass. Hail tears the large leaves to pieces, as was observed in a severe hail-storm at Dehra Dun in February 1913. In northern India the season's growth stops in November–December, and new growth starts in March. The leaves turn yellow about November–December, and commence falling in December–January; by March they have usually all fallen.

The following measurements in experimental plots at Dehra Dun give some indication of the rate of growth of young plants under different conditions, and exhibit the marked effect of weeding:

Terminalia belerica: rate of growth of young plants, Dehra Dun.

Condition under which grown.	Height at end of season.				
	1st season.	2nd season.	3rd season.	4th season.	5th season.
1) In nursery, weeded and watered	0 ft. 6 in.–0 ft. 8 in.				
2) Transplants of 1st rains, not weeded or watered subsequent to transplanting	Maximum 0 ft. 6 in.	Maximum 1 ft. 6 in.	1 ft. 2 in.– 2 ft. 0 in.	2 ft. 6 in.– 3 ft. 7 in.	4 ft. 11 in.– 5 ft. 8 in.
3) Fruit scattered on ground as under natural conditions; subsequently weeded. Sunny locality	Maximum 0 ft. 5 in.	2 ft. 6 in.– 3 ft. 2 in.	4 ft. 5 in.– 10 ft.	Maximum 12 ft. 9 in. (girth 0 ft. 7 in.)	
4) Fruit scattered on ground as under natural conditions; not subsequently weeded. Sunny locality	0 ft. 4 in.–0 ft. 7 in.	0 ft. 7 in.– (heavy grass and weeds) 0 ft. 9 in.			
5) Fruit scattered on ground as under natural conditions; not subsequently weeded. Sunny locality	Maximum 0 ft. 5 in.	Maximum 1 ft. 3 in.	Maximum 2 ft. 7 in.	Maximum 5 ft. 10 in.	
6) Fruit scattered on ground as under natural conditions; not subsequently weeded. Moderate side shade	Maximum 0 ft. 8 in. (heavy growth of weeds)	Maximum 0 ft. 11 in.			
7) Fruit scattered on ground as under natural conditions; not subsequently weeded. Heavy shade	Maximum 0 ft. 6 in.	0 ft. 3 in.– 0 ft. 10 in.			

SILVICULTURAL CHARACTERS. The tree is a light-demander, though it can stand slight shade in youth. It is decidedly sensitive to frost, all records of severe frosts agreeing in this respect; the leaves are usually found to be touched by frost more readily than those of almost any of its associates. As regards drought it is somewhat more hardy, though it does not occur in very dry localities. In the abnormal drought of 1907 and 1908 in the sal forests of Oudh it proved to be fairly hardy, while it was not affected in the severe drought of 1899 and 1900 in the Indian Peninsula.

It coppices fairly well. Measurements made by Mr. C. M. McCrie at Ramgarh in the Gorakhpur district, United Provinces, showed an average varying from 1 to 2.5 shoots per stool in coppice coupes of different ages up to fifteen years old. Measurements made by me in 1911 in the Tikri forest, Gonda, United Provinces, gave for coppice one year old an average height of 5 ft., and an average of two shoots per stool, as against 4.7 ft. and 2.2 shoots

respectively for sal. Experiments in 1909 in North Chanda, Central Provinces, showed a poor pollarding capacity, while the results of coppice fellings were on the whole good; the percentage of stools which coppiced successfully in different months being: (1) April, nil; (2) May, 100; (3) June, 100; (4) July, 100; (5) September, 50.

NATURAL REPRODUCTION. The consumption of the fleshy portion of the fruit and the dissemination of the hard nuts by animals has already been alluded to. Where the flesh is not so consumed it rots off or is eaten off by white ants, the nuts often being wholly or partially buried in the process. Germination takes place at different times during the rainy season. Successful germination is greatly assisted if the nuts are buried by rain, by white ants, or otherwise, since the radicle of the germinating seedling is liable to be eaten by birds and insects or to dry up if exposed to the sun. A considerable degree of moisture is necessary to stimulate germination, and it has been found by experiment that germination takes place more readily in moist places under shade, particularly if the nuts are buried, than in places exposed to the sun.

The high germinative power of sound seed and the comparative ease with which the seedling establishes itself would indicate that the tree should be more gregarious than it is. There can be little doubt that its sporadic character is due to the fact that the seed is so much subject to the attacks of animals and insects that a comparatively small proportion reaches the germinating stage.

ARTIFICIAL REPRODUCTION. Experiments in direct sowing have not been tried, but transplanting during the first rainy season, before the taproot has become too long, has proved quite successful. The nuts or the whole fruits should be sown in the nursery in March or April, covered with earth and watered regularly. Germination usually takes place about one to two months after sowing. Transplanting should be done in wet weather, and may be carried out either after pruning the stem and roots or with stem and roots intact; the latter gives the better results, the former checking the growth considerably.

RATE OF GROWTH. The rate of growth is moderate, or under favourable conditions rapid. The following records are available of girth measurements of trees in sal forest sample plots in the United Provinces:

Terminalia belerica: girth measurements in sample plots, United Provinces.

Forest division.	Locality.	No. of years under observation.	No. of trees under observation.	Girth classes.	Mean annual girth incremen for the period.
				ft.	in.
Saharanpur	Dholkhand and Malowala	7 and 12	2	0-1	0-30
			1	3-4	0-86
South Kheri	Bhira range	8 and 9	1	1-2	0-38
			2	2-3	0-54
Lansdowne	Chaukhamb	17	6	1½-4	0-34
	Jogichaur	—	1	3-4	0-80
	Kauria	4	1	6-8	0-49
	Gewain	12	2	1½-3	0-10
Haldwani	Khonani	6	2	3-4	0-46

A tree raised from seed sown in 1901 by Mr. Haines in the forest garden at Chaibassa, Chota Nagpur, attained in sixteen years a height of 36 ft. and a girth of 2 ft. 1½ in.

Gamble's specimens gave three to seven rings per inch of radius, representing a mean annual girth increment of 0.9 to 2.1 in., which is rapid.

As regards coppice, measurements by Mr. C. M. McCrie in 1910 in the Ramgarh coppice coupes, Gorakhpur, gave the following results :

Terminalia belerica : rate of growth of coppice, Ramgarh, Gorakhpur, United Provinces.

Age. years.	Mean girth. in.	Mean height. ft.
2	—	4
4	2	8
6	3	11
8	3.8	14
10	4.6	16.5
12	5.5	19
14	6.3	21

2. *Terminalia Chebula*, Retz. Syn. *T. tomentella*, Kurz. Myrabolan tree. Vern. *Harra*, Hind. ; *Hirda*, Mar. ; *Anale*, Kan. ; *Kadakai*, Tam. ; *Karaka*, Tel. ; *Panga*, Burm.

A moderate-sized to large deciduous tree with a rounded crown, spreading branches, and usually a short trunk, though in Burma it often grows tall and straight. Bark dark brown, often longitudinally cracked, exfoliating in woody scales. Wood very hard, fairly durable, used for building, agricultural implements, and other purposes. The tree is important mainly on account of its fruits, which are the best of the commercial myrabolans used for tanning.

DISTRIBUTION AND HABITAT. Throughout the greater part of India and Burma in mixed deciduous forests, extending into forest of comparatively dry types. It ascends to considerable elevations, up to 5,000 ft. in the outer Himalaya, and according to Bourdillon, up to 6,000 ft. in Travancore in localities where the rainfall is light. In Burma it occurs in deciduous forests both of the upper and of the lower mixed types, along with teak, *Terminalia tomentosa*, and their associates : it occurs also in *indaing* forest on laterite, along with *Dipterocarpus tuberculatus* and its companions. It extends to the borders of the dry zone of Burma, but is not a characteristic tree of the drier parts of that zone. It is found on a variety of geological formations, and on clayey as well as on sandy soil. In the Central Provinces it is particularly common on metamorphic rocks in open forest or village lands, but also occurs on other geological formations. In Bombay it is common on Deccan trap, and Talbot notes that on the laterite of the Mahableshwar plateau at 4,500 ft. it is one of the principal constituents of the low elfin-wood forest. It is also a characteristic tree of other special types of dry forest. Thus in the Goalpara district of Assam it is common in the *bhabar* tract fringing the base of the outer hills on deep boulder formation in mixture with sal and *Lagerstroemia parviflora* in a dry stunted type of forest of a pronounced deciduous character : again, in the Kangra valley it grows gregariously in rather stunted form on poor rocky ground at about 3,500 ft. elevation, either pure or mixed with *Pinus longifolia*.

In its natural habitat the absolute maximum shade temperature varies from 98° to 118° F., the absolute minimum from 30° to 60° F., and the normal rainfall from 30 to 130 in.

LEAF-SHEDDING, FLOWERING, AND FRUITING. In some localities the leaves commence falling in November, and by February or March the trees are usually leafless. The new leaves appear from March to May; they are light green or sometimes copper coloured. The spikes of greenish white flowers appear with the new leaves. In the Himalayan valleys flowering may take place as late as June. In the Central Provinces, Haines says flowering takes place to a small extent in July–August, in addition to the usual flowering in April–May.

The fruits ripen from November to March, according to locality, and fall soon after ripening. The fruit (Fig. 194, *a*) is a somewhat hard drupe 1–2 in. long, obovoid, ellipsoidal or ovoid, yellow to orange brown, sometimes tinged with red or black, 5-ribbed when dry; the nut (putamen) is 0.7–0.8 in. by 0.5–0.6 in., ovoid, pale yellow, rough, hard, sub-angular. For commercial purposes the fruits are collected when quite ripe and spread out in the sun until thoroughly dry. The fruit crop varies from year to year. About 35 to 45 fresh fruits, or 60 to 75 dry fruits, weigh 1 lb.

The germinative power of the seed is poor. The precise cause of this has not been ascertained; Mr. J. E. C. Turner,¹ writing of conditions in Bombay, says that germination is generally backward with regard to the ridged fruits, but that those known locally as *bhonga*, in which the fleshy portion has been transformed into a black powder, presumably by a fungus, germinate readily. Tests at Dehra Dun with whole fruits as well as with nuts from which the outer fleshy covering was removed, invariably gave poor results. The results were better in the shade than in the sun. It was also found that the seed retained its fertility to a small extent for one year.

GERMINATION (Fig. 194, *b-f*). Epigeous. The hard putamen splits in two and the radicle emerges from one end; the cotyledonary petioles elongate, arching slightly and raising above ground the cotyledons, which are convolute in the seed and unroll on emerging. The young stem then issues from between the cotyledons, and the discarded pieces of the putamen remain in or on the ground.

THE SEEDLING (Fig. 194).

Roots: primary root moderately long, somewhat thin, terete, tapering, wiry, yellow turning brown: lateral roots moderate in number and length, fibrous, distributed down main root. **Hypocotyl** distinct from and much thicker than root, 0.3–0.6 in. long, somewhat compressed and quadrangular, yellow turning green, pubescent, scarcely emerging from the soil. **Cotyledons:** petiole 1–1.5 in. long, flattened above, yellow or pinkish turning green, tomentose: lamina 0.9–1 in. by 1.5–1.7 in., foliaceous, somewhat fleshy, reniform or broadly orbicular, apex truncate or retuse, base acute, entire, yellow at first, becoming green on expanding, pubescent near base on both surfaces, glabrous elsewhere, with three prominent and two less conspicuous veins from the base, veins prominently branched. **Stem** erect, zigzag at the nodes, terete, green, rusty pubescent; internodes 0.5–1.2 in. long. **Leaves** simple,

¹ Ind. Forester, xxxiii (1907), p. 362.



FIG. 194 *Terminalia Chebula* SEEDLING $\times \frac{1}{2}$

a Fruit b f—Germination stages g h Development of seedling during first season

alternate, exstipulate. First leaf sometimes under 0.3 in. long, ovate lanceolate, acute or acuminate, pubescent. Subsequent leaves with petiole 0.1–0.2 in. long, tomentose; lamina 0.8–4.5 in. by 0.5–2 in., ovate, acute, entire, pubescent, bright green above, somewhat paler beneath, venation arched reticulate, lateral veins 4–10 pairs.

The young seedling of this species can be distinguished from those of *T. tomentosa* and *T. Arjuna* by the length of the hypocotyl and the cotyledonary petioles (see p. 519).

The growth of the seedling is comparatively slow, a height of about 4–8 in. being ordinarily attained by the end of the first season, increasing to 1–2 ft. by the end of the second season. The year's growth ceases about November; the leaves commence falling that month, and the seedling is leafless in January–February, new growth commencing about March (Dehra Dun). Young plants are fairly frost-hardy.

SILVICULTURAL CHARACTERS. The tree is a light-demander, though in youth it stands slight shade and even benefits by side protection from the sun. It is fairly hardy against frost as well as drought. It withstands fire well, and has good powers of recovery from burning. It coppices fairly well.

NATURAL REPRODUCTION. The fallen fruits often become partially buried by rain, the soil round them being blackened with the tannin they contain. The fleshy portion becomes partly eaten by white ants or disintegrates, leaving the hard nut exposed. Germination takes place in the rainy season, sometimes not until the end of that season, or in some cases not until the following year. The scarcity of natural reproduction in some localities is very noticeable, and is a matter which requires further study. Where the collection of myrabolans is carried out extensively, the removal of the fruits would be sufficient to account for it. On the other hand, the lack of reproduction may be attributable to some extent to the poor germinative power of the seed and to the fact that it is much subject to the attacks of insects, rats, and squirrels. Numerous fruit-stones found lying ungerminated after the end of the rainy season have been split open, and almost invariably the seed has been found to be destroyed by insects. The seed germinates better if it has become covered with earth or débris than if it is lying in the open.

ARTIFICIAL REPRODUCTION. Sowings on mounds, in patches or trenches, and otherwise have been carried out for years, but with very indifferent success, owing in part at least to the poor germinative power of the seed and to its liability to the attacks of insects, squirrels, and rats.

Experiments at Dehra Dun showed that transplanting from the nursery can be carried out successfully in the first or second rainy season. The most successful method of raising plants in the nursery was found to be by drying the fruits thoroughly, removing the hardened fleshy covering, and sowing the fruit-stones in boxes before the rainy season, covering them with earth and watering them regularly. Even with this treatment a success of only 20 per cent. was attained. Soaking the fruits in moist manure for some days was found to have no effect in stimulating germination. For artificial reproduction the fruits should be collected from the ground as soon as they fall, and not off the tree.

RATE OF GROWTH. The rate of growth is slow. The following measurements of trees in sal forest sample plots have been recorded :

Terminalia Chebula : records of girth measurements in sample plots.

Province.	Forest division.	Locality.	No. of years under observation.	No. of trees under observation.	Girth classes.	Mean annual girth increment for the period.	
					ft.	in.	
United Provinces	Dehra Dun	Nagsidh and Thano	17 and 20	{	6	1-2	0.25
					4	2-3	0.29
					2	4-5	0.37
	Lansdowne	Chaukhamb	17	11	1½-6	0.56	
		Jogichaur	4	1	1½-3	0.38	
Barswar		4	15	1½-3	0.27		
„	South Kheri	Bhira (Kishanpur)	9	{	1	1-2	0.22
					1	2-3	0.12
Bihar and Orissa	Singhbhum	Tirilposi	18	{	2	3-4	0.70
					1	4-5	0.67
Central Provinces	Balaghat			30	2-3	0.16	

Gamble's specimens showed six to ten rings per inch of radius, representing a mean annual girth increment of 0.63 to 1.05 in.

Coppice measurements showed an average height of 8 ft. and 8.5 ft. in five years in Dehra Dun and Gorakhpur respectively.

3. *Terminalia tomentosa*, W. and A. Vern. *Sain, ain, saj, asna, asan*, Hind. ; *Matti*, Kan. ; *Sadada*, Guz. ; *Maddi, nallamaddi*, Tel. ; *Karra marda*, Tam. ; *Taukkyan*, Burm.

A large deciduous tree with a long clean bole and a full crown. Bark grey to black, with deep longitudinal fissures and transverse cracks dividing it into oblong scales, red inside. Wood dark brown with darker streaks, hard, strong, of variable durability, used for building, carts, railway wagons, mine props, bedsteads, and other purposes : it lasts well under water.

The thickness of the bark varies with size and other conditions : the following figures give the average of a number of measurements made in the Dehra Dun district :

Girth of tree.	Bark thickness.	Girth of tree.	Bark thickness.
	in.	ft.	in.
0-6 in.	0.2	3-4	1.0
6 in.-1 ft.	0.35	4-5	1.1
1-2 ft.	0.5	5-6	1.1
2-3 ft.	0.8	6-7	1.2

Apart from its economic value the tree is important silviculturally as being one of the commonest of Indian forest trees and being suitable for afforesting clayey ground. In favourable localities it attains a girth of 12 ft. or more and a height of over 100 ft., but on dry rocky ground and other unfavourable situations it is stunted.

It is somewhat variable, particularly as regards its leaves, which as a rule are large and tomentose in less favourable localities and smaller and more glabrous in localities in which it grows best.

DISTRIBUTION AND HABITAT. *General distribution.* *Terminalia tomentosa*

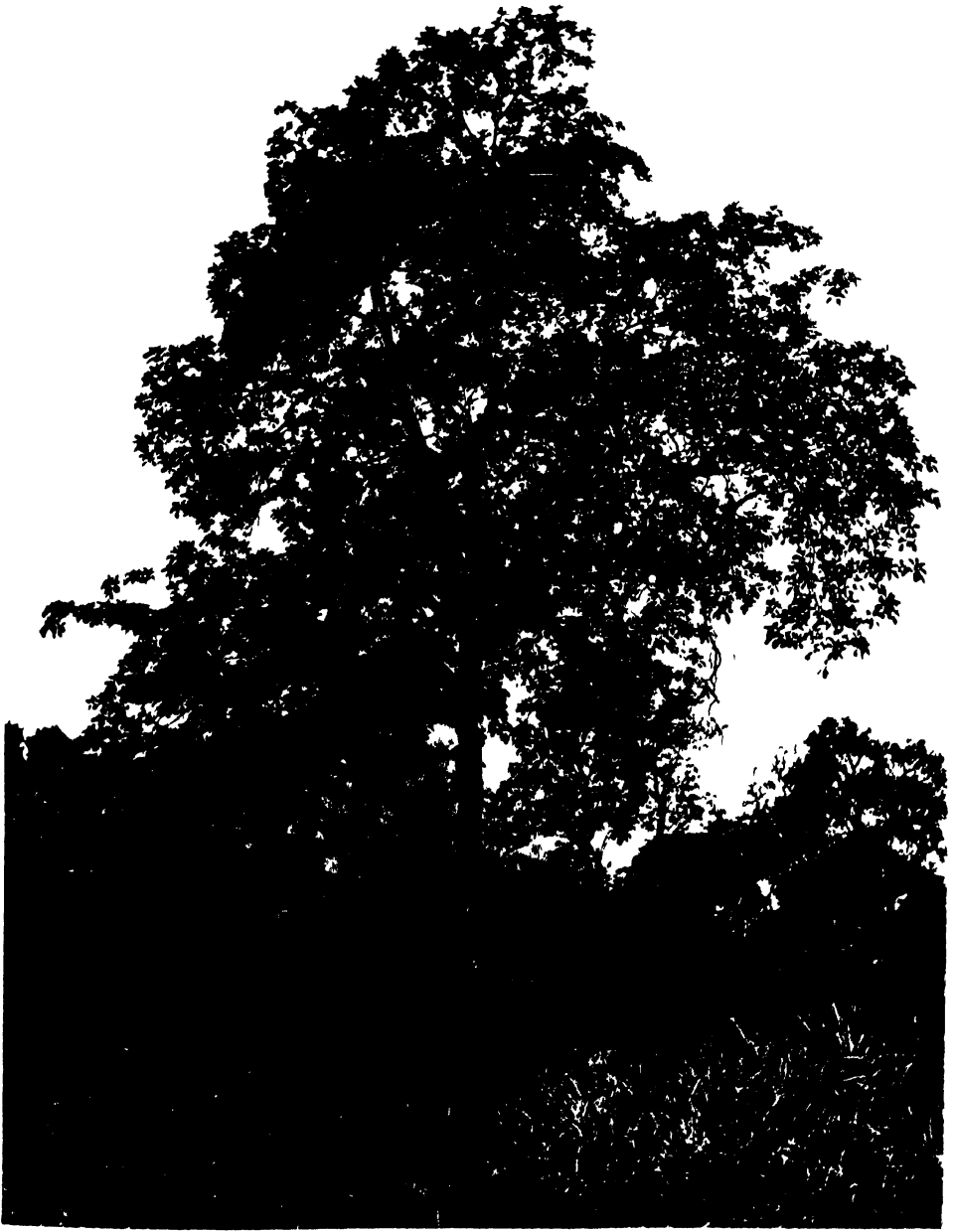


FIG. 195 *Terminalia bitorica*, United Provinces



FIG. 196 *Terminalia tomentosa*, tree 12 ft 4 in. in girth and 115 ft in height on alluvial ground, Gonda district, United Provinces.

is one of the commonest and most widely distributed of Indian forest trees. It extends throughout the sub-Himalayan tract from the Ravi eastwards, ascending the outer hills to 4,000 ft. : it is not common east of the Jalpaiguri district of Bengal, and is rare in most parts of Assam. It is not found in Sind and Rajputana, but is common throughout the greater part of the Indian Peninsula, extending into comparatively dry regions. It is plentiful throughout the greater part of Burma, extending into the dry zone and ascending to 4,000 ft. in the Southern Shan States.

Climate. In its natural habitat the absolute maximum shade temperature varies from 95° to nearly 120° F., the absolute minimum from 30° to nearly 60° F., and the normal rainfall from 30 to 150 in.

Soil. The tree attains its largest dimensions on deep rich alluvial soil. On poor shallow soil, particularly on hilly ground, though often plentiful it remains stunted. It favours stiff clayey soil, where it often becomes gregarious in depressions and round the edges of swamps. It grows freely on black cotton soil, though it remains stunted. It is abundant on laterite in some localities, though here also it is stunted.

Local distribution and forest types. *Sub-Himalayan tract.* In the sub-Himalayan tract *Terminalia tomentosa* is abundant in the sal forests, becoming gregarious on flat clayey ground and in grass-covered depressions which usually mark the sites of former ponds or watercourses and which have gradually filled up. In such places it is probable that the tree acts as a useful draining agent, for it is noticeable that sal reproduction eventually makes its way into these areas underneath it. That it is not specially partial to badly drained clayey ground, though it is capable of growing there, is shown by the fact that it occurs in quantity and shows its best development on well-drained ground. In the sal forests, besides the sal (*Shorea robusta*) its principal associates are *Lagerstroemia parviflora*, *Terminalia belerica*, *Adina cordifolia*, *Ougeinia dalbergioides*, *Anogeissus latifolia*, *Stereospermum suaveolens*, *Eugenia Jambolana*, *E. operculata*, and *Buchanania latifolia*.

A special type of forest, in which *Terminalia tomentosa* occurs pure or mixed with *Anogeissus latifolia* on rich alluvial ground beside rivers, is a feature of some of the submontane forests and is well exemplified in the Gonda district of the United Provinces. The evolution of this type is explained on p. 523 under 'natural reproduction' and is shown in Figs. 197-200. Fig. 200 gives a good idea of the appearance of a crop of this type approaching maturity. On rich alluvial ground of this kind it reaches magnificent proportions, as may be judged from Fig. 196, showing a tree 12 ft. 4 in. in girth and 115 ft. high.

In the Siwalik hills and outer Himalaya it is common and sometimes gregarious, often on somewhat poor soil, but here it reaches only a small size. In the Himalaya it ascends to about 4,000 ft. It extends westward to the Kangra hills, and possibly to a small extent farther west.

In the eastern part of the sub-Himalayan tract it reaches very large dimensions, for instance in the Tista forests, where it occurs both in sal forest and in low-level mixed forest without sal. In Jalpaiguri it is not plentiful, though there are some well-grown trees in the Upper Tonda forest : east of this district it is not common, and is more often absent altogether. In the

Bengal Duars it mixes with *T. myriocarpa*, but farther east the latter replaces it largely if not entirely.

Chota Nagpur. In Chota Nagpur the tree is common, particularly in valleys and moist localities. On village lands it is very common, and is extensively pollarded for the cultivation of the tasar silkworm. It is a common constituent of the sal forests, while in some valleys it occurs along with *Bombax malabaricum* and other species without sal, probably owing to insufficient drainage.

Central Provinces and Berar. *Terminalia tomentosa* is common in deciduous forests throughout the greater part of the Central Provinces and Berar; it is a common companion of the sal as well as of the teak. It is plentiful on black cotton soil, which many species avoid, but here it is usually small. It reaches its best development on moist fertile alluvium near rivers, where it sometimes tends to be gregarious.

In the usual mixed deciduous type, in which teak may or may not be present, its chief companions are *Pterocarpus Marsupium*, *Terminalia belerica*, *T. Chebula*, *T. Arjuna* (along streams), *Anogeissus latifolia*, *Ougeinia dalbergioides*, *Bassia latifolia*, *Lagerstroemia parviflora*, *Diospyros Melanoxyton*, *Buchanania latifolia*, *Soymida febrifuga*, *Adina cordifolia*, *Dalbergia latifolia*, *Cleistanthus Collinus*, *Chloroxyton Swietenia*, *Butea frondosa*, as well as many other species of less importance. Sometimes a special type is found in moist valleys on flat ground where the soil is fair to good and often clayey, the chief associates being *Cleistanthus Collinus*, *Bassia latifolia*, *Anogeissus latifolia*, *Ougeinia dalbergioides*, *Buchanania latifolia*, and a few other species.

Bombay. *Terminalia tomentosa* is plentiful in most of the forest tracts of the Bombay Presidency, being perhaps nowhere more abundant than in Kanara and in the Dangs forests of Surat; in parts of the latter forests there are sometimes as many as 30 mature trees per acre, while in the Mungod high forest of the East Kanara division it forms 23 per cent. of the crop. In Kanara it grows better on granite and schist than on laterite. In the Deccan it prefers black cotton soil to the shallow soils of the quartzite hills so frequent in that region. It occurs in nearly all types of mixed deciduous forest, ascending to between 3,500 and 4,000 ft. on the Nasik ghats and the Khandesh Akrani, but is absent from the laterite of the Mahableshwar plateau. It thrives best in the moister localities, particularly in valleys on alluvial ground, becoming gregarious on clayey soil. At the higher elevations, in exposed situations and on poor soil, it becomes stunted. In the Kanara forests, where the number of species is considerable, its most important companions are teak, *Dalbergia latifolia*, *Lagerstroemia lanceolata*, *L. parviflora*, *Xylia xylocarpa*, *Pterocarpus Marsupium*, *Anogeissus latifolia*, *Terminalia paniculata*, and *Adina cordifolia*. It shows a marked tendency to occupy the more level ground where the soil is deep and moist. In the mixed forests of somewhat drier localities it is found with teak, *Anogeissus latifolia*, *Lagerstroemia parviflora*, *Bassia latifolia*, *Ougeinia dalbergioides*, *Buchanania latifolia*, *Diospyros Melanoxyton*, *Dalbergia latifolia*, *Cassia Fistula*, *Phyllanthus Emblica*, and many other species.

Southern India. Although not so common as in Bombay, the tree is fairly

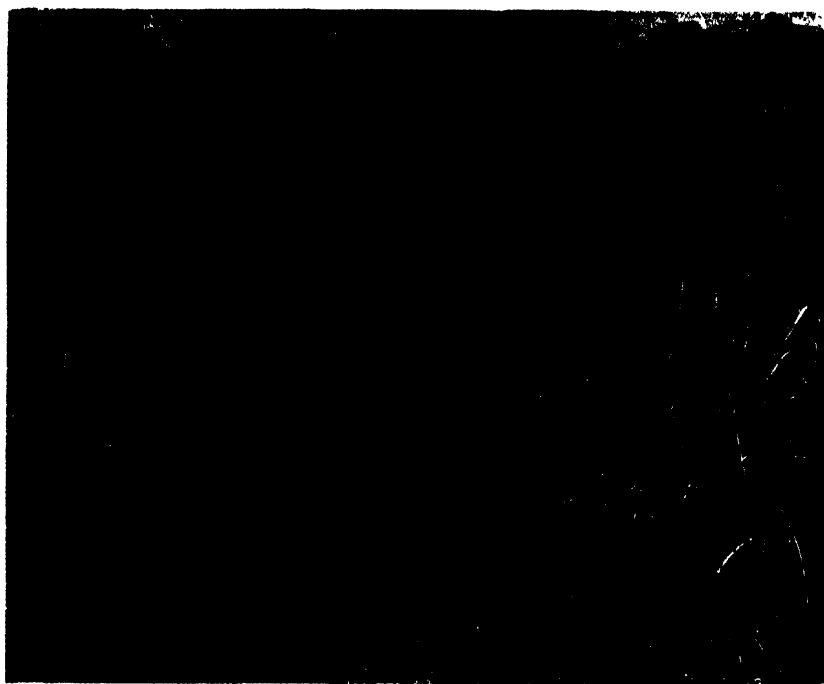


FIG. 197. *Terminalia tomentosa*, establishment of pure crops on alluvial ground, Gonda district, United Provinces : (1) natural seedlings up to 20 ft. high appearing on comparatively recent alluvium.



FIG. 198. *Terminalia tomentosa*, establishment of pure crops on alluvial ground, Gonda district, United Provinces : (2) natural reproduction up to 8 ft. high ; older forest of *Terminalia tomentosa* on older alluvium behind.



FIG. 199 *Terminalia tomentosa*, establishment of pure crops on alluvial ground, Gonda district, United Provinces (3) young crop about 15 ft. high - older alluvial crop on left behind



FIG. 200 *Terminalia tomentosa*, establishment of pure crops on alluvial ground, Gonda district, United Provinces (4) forest approaching maturity

well distributed in Madras, and in some localities it is plentiful. It is characteristic of various types of mixed deciduous forest, and in Ganjam is a common companion of the sal. It is fairly plentiful in the Wynaad, and ascends to 4,200 ft. in the Nilgiris. In Coorg it is one of the commonest species in the deciduous forests, and attains very fair dimensions. It is common in many parts of Hyderabad and Mysore, and is very common in Travancore up to 2,000 ft.

Burma. *Terminalia tomentosa* is common in most of the mixed deciduous forests throughout Burma, both in the upper and in the lower mixed types, as well as in *indaing* (dry dipterocarp) forest. It is sometimes found in dense evergreen forest, for example on alluvial flats along streams in some parts of the Upper Chindwin, but here the evergreen has probably encroached on a former deciduous type of forest.

In the upper mixed forests, which are found on hilly or undulating ground, it is characteristic more of the dry than of the moist types, its chief companions being teak, *Xylia dolabriformis*, *Acacia Catechu*, *Sterculia* spp., *Homalium tomentosum*, *Dalbergia cultrata*, *Terminalia Chebula*, *Vitex glabrata*, *Pterocarpus macrocarpus*, *Odina Wodier*, *Adina cordifolia*, *Anogeissus acuminata*, and others, and in the drier parts *Pentacme suavis* and *Shorea obtusa*. The chief bamboos are *Dendrocalamus strictus* in the driest types, *Bambusa polymorpha* in the moister types, and in intermediate types *Cephalostachyum pergracile*, and in Upper Burma *Thyrsostachys Oliveri*; *Bambusa Tulda* often occurs with it on alluvial flats.

It is very plentiful in certain types of lower mixed forest on flat alluvial land tending towards dry rather than moist conditions. A case in point is the Satpôk forest of the Tharrawaddy district, where after teak it is the commonest tree, these two species being far more plentiful than any other. Although flat, the locality is fairly well drained; the chief associate species are *Xylia dolabriformis*, *Lagerstroemia Flos-Reginae*, *Berrya Ammonilla*, *Adina cordifolia*, *A. sessilifolia*, *Stephegyne diversifolia*, *Terminalia Chebula*, *T. belerica*, *Odina Wodier*, *Eugenia Jambolana*, and *Eriolaena Candollei*. The rainfall in this tract is about 80 in.

The following figures based on complete enumerations in the Satpôk forest give some idea of the prevalence of this tree in some of the compartments: ¹

Stock of *Terminalia tomentosa* trees in certain compartments in the Satpôk forest, Tharrawaddy district, Burma.

Compartment No.	Area in acres.	Number of trees.			
		I 7 ft. girth and over.	II 6 to 7 ft. girth.	III 4½ to 6 ft. girth.	IV 3 to 4½ ft. girth.
2	178	192	250	470	508
4	178	235	283	383	437
8	178	176	173	357	717
9	178	128	141	214	487
24	178	122	114	295	524
25	178	177	193	310	372

¹ Working Plan for the Satpôk, Sitkwin, and Thindawyo Reserves, Tharrawaddy, R. S. Troup, 1906.

The tree extends into the open scrub forests of the dry zone of Upper Burma, but even outside that zone it is characteristic of certain dry types of poor open bamboo forest on shallow soil, where the trees attain small dimensions. This type is exemplified in parts of the Ruby Mines district, where the chief associate species are *Xylia dolabriformis*, *Pterocarpus macrocarpus*, *Diospyros burmanica*, *Acacia Catechu*, *Adina cordifolia*, *Odina Wodier*, and others, with *Terminalia Oliveri* in the drier parts; the chief bamboo is *Dendrocalamus strictus*. In the dry zone proper the rainfall varies from 22 in. to about 50 in., but it is doubtful if the tree occurs in tracts where it is less than 30 in. The geological formation consists mainly of soft sedimentary unaltered sandstones and shales. *Terminalia tomentosa* is common, but its growth is stunted; its chief associates are *Terminalia Oliveri*, *Tectona Hamiltoniana*, *Acacia Catechu*, *A. leucophloea*, *Buchanania latifolia*, *Diospyros burmanica*, *Odina Wodier*, *Schleichera trijuga*, and sometimes *Xylia dolabriformis* of small size.

A variety with larger leaves and fruits (var. *macrocarpa*, Kurz) is characteristic of *indaing* forest, chiefly on laterite, in association with *Dipterocarpus tuberculatus*, *Pentacme suavis*, *Shorea obtusa*, *Melanorrhoea usitata*, *Buchanania latifolia*, *Diospyros burmanica*, and other species. Where the soil becomes stiff and clayey *Terminalia tomentosa* becomes the predominating species and may form entirely pure crops, often of an open description with a soil-covering mainly of grass.

LEAF-SHEPPING, FLOWERING, AND FRUITING. In northern India the leaves usually commence falling in January or February, and by March or April, and in dry places as early as February, the trees are leafless, though the dead leaves sometimes hang on the trees for some time. This is one of the latest forest trees to acquire its new foliage, and in northern India the new leaves only begin to appear about the end of June. Farther south they appear about April–May. The paniced spikes of small whitish flowers appear about July in northern India and about May–June farther south. In the early part of the rainy season a forest of *Terminalia tomentosa* is a beautiful sight with the masses of whitish blossom against the delicate green of the young foliage. The fruits form rapidly, becoming full-sized by about October, though still green; they remain pale yellowish green from November to January, ripening about February–March. The fruit (Fig. 201, *a*) has a hard bony axis with five coriaceous wings, and is brown when ripe. The ripe fruit falls chiefly from March to May, but many unripe fruits, usually found to be bitten off by insects or possibly birds, fall during January–February, and turning brown after falling give the false impression of being ripe. Parrots often destroy much of the fruit crop prematurely. The ovary is often attacked by a *Cynips*, which prevents the formation of the fruit and produces bunches of galls which may be mistaken for fruits, though they have no resemblance to the characteristic winged fruits.

So far as tests show, the percentage of fertility of the seed is comparatively low. In a number of tests carried out at Dehra Dun the maximum percentage obtained was only 45, except in one case in which 78 per cent. was obtained. Possibly these poor results are due partly to the difficulty in discriminating between good and bad (i. e. prematurely fallen) seed when the fruits are

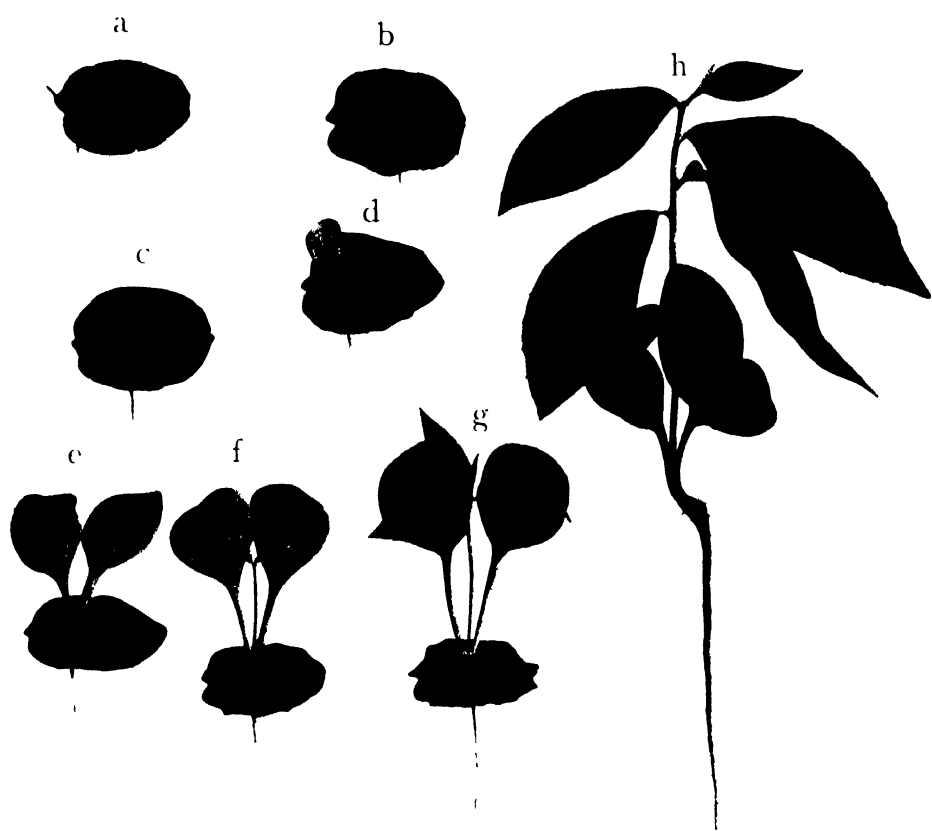


FIG. 201. *Terminalia tomentosa* SEEDLING $\times 3$

a Fruit b - e Germination stages f - h Development of seedling to end of first season

collected from the ground, but in any case this would represent the actual conditions so far as natural reproduction is concerned. In seven different samples of fruits from northern India the number weighing 1 lb. varied from 150 to 250.

Records of seed-years extending over a series of years in various localities show that fair to good seed-years are the rule, though occasional bad seed-years occur at varying intervals.

GERMINATION (Fig. 201, *b-e*). Epigeous. The hard endocarp of the fruit opens slightly and the radicle emerges. The cotyledonary petioles elongate by arching and the large foliaceous cotyledons, which are convolute in the seed, extricate themselves and unroll. The cotyledons are raised above ground by the further elongation of their petioles, from between which the young shoot emerges.

THE SEEDLING (Fig. 201).

Roots : primary root moderately long and thick, terete, tapering, brown, upper part, immediately below ground-level, swollen, with a characteristic bend due to the efforts of the seedling to escape from the hard endocarp of the fruit during germination ; lateral roots moderate in number and length, fibrous, distributed down main root. *Hypocotyl* distinct from root, 0.2 in. long, green, immediately below or on surface of ground. *Cotyledons* : petiole 0.8-1.5 in. long, flattened above, green, pubescent : lamina 1.2-1.4 in. by 1-1.5 in., foliaceous, somewhat fleshy, broadly and often obliquely obovate orbicular, apex truncate or retuse, base tapering and slightly decurrent, bright green, glabrous, with five prominent veins from the base. *Stem* erect, terete, green, tomentose ; first internode, above cotyledons, 1.8-2.5 in., subsequent internodes 0.1-0.7 in. long. *Leaves* simple, exstipulate, alternate, rarely sub-opposite, first pair not opposite. Petiole 0.1-0.2 in. long, tomentose. Lamina 1.3-4 in. by 0.8-1.6 in., elliptical ovate or obovate, apex and base acute, entire, pubescent or glabrescent above, pubescent beneath, tomentose round margin and on principal veins beneath, lateral veins 6-8 pairs in young seedlings ; two small glands present, one on either side of midrib near base of lamina on under surface.

The cotyledons of *T. tomentosa*, *T. Arjuna*, and *T. Chebula* are somewhat similar, but in the germinating stages the seedlings can be readily distinguished by the lengths of the hypocotyls and cotyledonary petioles, thus :

Cotyledonary petioles short (0.3-0.6 in.) ; hypocotyl long (2.2-3 in.)—*T. Arjuna*.

Cotyledonary petioles long (0.8-1.5 in.) ; hypocotyl moderately long (0.3-0.6 in.)—*T. Chebula*.

Cotyledonary petioles long (0.8-1.5 in.) ; hypocotyl very short (0.2 in.)—*T. tomentosa*.

During the first season the growth of the seedling is only moderate, a height of 4-7 in. being ordinarily attained under natural conditions, while even with regular watering and weeding a height of more than 1 ft. is seldom reached, though occasionally a height of 18 in. or more may be attained. The taproot reaches a length of about 6-10 in. within two months of germination. In the subsequent growth of the young plant height is sacrificed to a branching or straggling growth, long branches being produced which bend over towards the ground, and no definite upward leader being formed for

some time ; this form of straggling or bushy growth is characteristic of certain other species of *Terminalia*, e. g. *T. Arjuna* and *T. myriocarpa*.

The seedlings are fairly hardy against drought, but are more sensitive to frost. They stand moderate side shade, but are intolerant of heavy overhead shade ; in experimental plots at Dehra Dun it was found that few seedlings survived heavy shade more than one season, while all succumbed before the end of the second season. The cotyledons are subject to the attacks of birds, and the seedlings are browsed by deer and cattle and are uprooted by pigs.

In the forest, seedlings of *Terminalia tomentosa* often pass unrecognized, since the leaves of young seedlings are very different from those of older plants, the leaves being much smaller, more pointed, and more conspicuously hairy. A characteristic feature of seedlings of the first year is a swelling and decided bend where the taproot joins the stem immediately below ground-level, at the point where the seedling escaped from the hard fruit during germination.

SILVICULTURAL CHARACTERS. *Terminalia tomentosa* is a light-demander, and is rapidly suppressed under shade. It cannot be called exacting as regards soil, being found on a variety of soils, and sometimes on dry hills with poor shallow soil. Although capable of existing on stiff clay better than most species it does not follow that this type of soil suits it best, for its development on deep well-drained soil is better.

In years of severe drought the tree has proved decidedly tender. In the abnormal droughts of 1899 and 1900 in the Indian Peninsula and 1907 and 1908 in Oudh it was badly affected, but in the latter case the sal suffered more severely than it did. As regards frost, the leaves are readily killed, but the damage is often more apparent than real, since the stems frequently remain untouched when all the foliage is withered. Young plants are, however, often killed back in frosty localities.

Young plants suffer less than sal from grazing, probably because they lose their leaves in the hot season, at which time the sal plants send up succulent young shoots. Mr. J. Best ¹ describes a curious form of growth due to excessive grazing in the Bhandara district of the Central Provinces. Considerable areas are covered with plants up to 18 in. in height, much branched and stunted in growth. On being dug up they are found to have a thick and distorted stem at or just beneath ground surface. This stunted growth is attributed more to trampling and hardening of the soil than to actual browsing, and it is pointed out that on steep hills where cattle do not graze this stunted growth is absent.

The tree has a deep root-system. It sometimes produces root-suckers where the roots are exposed, but as a rule sparingly. Trees up to medium size generally coppice and pollard well, but the coppicing power of trees more than about 4 ft. in girth is usually poor : stools of this size sometimes make a dying effort by producing an immense mass of small coppice-shoots and then succumb. In some districts, particularly in parts of Chota Nagpur, the Central Provinces, and elsewhere the tree is regularly pollarded for the growing of tasar silk : in parts of Bombay it is extensively lopped for ash manure

¹ Ind. Forester, xxxv (1909), p. 612.

for crops, while in some localities it is lopped for cattle fodder. The coppicing and pollarding power appears to vary. Experiments carried out in the Chanda district of the Central Provinces in 1909 showed that of eleven different species coppiced and pollarded *Terminalia tomentosa* showed the poorest results under either method. As regards coppice, the percentage of stools which produced shoots when cut in different months from April to September was: April, 66; May, 66; July, 40; August, nil; September, nil. Coppicing experiments in North Khandesh, Bombay, in 1903 showed that 70 per cent. of the trees yielded coppice-shoots, 1-9 shoots per stool. Measurements which I made in 1911 in three coppice coupes one and two years old in the Gonda district, United Provinces, showed that out of 17 species *Terminalia tomentosa* showed the largest average number of shoots per stool in each of the coupes, namely 4.7 in the one-year-old coupe, and 4.7 and 2.9 in two coupes two years old.

A curious form of injury very prevalent among trees on the western side of the Indian Peninsula from North Kanara southwards to Malabar is that known as water-blister. This so-called blister is a ridge-like swelling on the side of the tree, apparently resulting from the healing over of a longitudinal crack in which sap or water has accumulated, so that when the blister is cut into a quantity of yellowish fluid is forced out under considerable pressure. There may be one or more blisters on a tree.

NATURAL REPRODUCTION. The natural reproduction of this important tree is not yet fully understood. Considering the comparatively low germinative power of the seed, the wide distribution and relative abundance of the species is remarkable, and points to some compensating advantage in its power of establishing itself under varying conditions. In forest tracts young seedlings may be found in large quantities after a good seed-year, indicating that even if a considerable proportion of the seed fails to germinate, the seedlings which survive from seed which does germinate are sufficiently plentiful.

Numerous experiments have been carried out at Dehra Dun to ascertain the conditions which favour natural reproduction, and so far as they go these experiments have shown that germination, which takes place early in the rains, is more successful on bare ground than where the fruits are scattered on grass or on low weeds. Although germination takes place fairly readily in the case of fruits lying on the surface of the ground, there is a higher percentage of success if they are slightly buried, as often happens under natural conditions on loose soil during the early showers preceding the rainy season. Moisture greatly stimulates germination, and thus the seed may germinate freely under the densest shade, though the seedlings do not survive for more than one season if the shade is at all heavy. Successful germination as well as establishment of seedlings is possible in the case of fruits lying on a layer of dead leaves both in the sun and under shade; this is not the case with sal, which fails to germinate on a layer of dead leaves in the sun, while under shade, although germination takes place, the seedlings do not survive more than one season where the leaf layer is thick. In a damp sodden growth of weeds the seedlings tend to rot during the first rainy season: otherwise they are capable of making their way through a moderate growth of grass and low weeds.

The effects of light and shade and of soil-covering at the time the fruit falls are indicated by the following results of experiments in six plots in the same locality at Dehra Dun :

Terminalia tomentosa : survival and development of seedlings.

Condition of plot.	Percentage of germination (100 fruits scattered in each plot).	Percentage and condition of survivors at end of first season.
(1) In full sunlight : on bare ground, not weeded subsequently	42	40 } Seedlings up to 6 in. high ; plots covered with grass up to 1 ft. high.
(2) In full sunlight : on short grass	14	12 }
(3) In moderate side shade : on bare ground, not weeded subsequently	29	28 } Seedlings healthy, up to 5½ in. high ; ground moist with heavy dew ; grass and weeds about 9 in. high.
(4) In moderate side shade : on short grass	5	4 }
(5) In dense overhead shade : on bare ground, not weeded subsequently	45	14 } Of which only 2 healthy, 4 in. high, on side of plot near light ; remainder dying.
(6) In dense overhead shade : on short grass	29	6 } Up to 5 in. high, only on side of plot near light.

The effect of light on natural reproduction has been further brought out in two plots in close proximity to each other at Dehra Dun, one plot being under the fairly heavy shade of bamboos and the other in the open. These plots were laid out with the view of ascertaining if sal seed scattered on the surface of a thick layer of leaves would germinate and the seedlings would establish themselves under shade and in the open respectively. The leaves in question were collected in the forest, and among them were a number of fruits of *Terminalia tomentosa*. In the shaded plot several seedlings appeared from these fruits during the rainy season in July and August : germination was very successful owing to the wet layer of leaves. Of the seedlings which appeared the survivals were only 4 in November, 2 in December, 1 in January, 1 in March, and none in July. It is probable that the mortality was due not only to shade but also to want of moisture, since the ground became decidedly dry after the rainy season was over ; this, however, would also hold under similar conditions in the forest. In the open (unshaded) plot ten seedlings appeared : although some of the fruits germinated on the dry upper layer of the dead leaves a number failed to do so, and this indicates that a thick layer of dead leaves in the open may prevent reproduction to some extent, though to nothing like the extent which it does in the case of sal, for the sal fruits fall after the season of leaf-shedding, whereas those of *Terminalia tomentosa* fall in the early part of it and therefore do not lie on the top of the leaves. These ten seedlings all survived, and by October of the second year varied from 1 ft. 5 in. to 4 ft. 2 in. in height ; some were amongst grass about 2 ft. high and others were quite in the open. This experiment clearly demonstrates the necessity for an abundance of light for successful natural reproduction.

To summarize, it may be said that these preliminary experiments indicate the following to be some of the main factors which favour the establishment of natural reproduction : (1) abundance of light, (2) a fair degree of soil moisture, (3) bare ground, (4) loose soil, enabling the fruits to be slightly

covered during the early showers, (5) absence of dense sodden grass and weed-growth. The influence of frost, fire, and grazing will be alluded to below.

Confirmation of the results of these preliminary experiments may frequently be met with by observations in the forest. The effect of light in particular is constantly noticeable. Vigorous young seedlings appear in quantity along roads, paths and fire-lines, and on open spaces. Dense masses of saplings establish themselves in gaps with complete overhead light, and the stronger ones eventually suppress the weaker.

An instance of the result of admitting light and clearing the ground is recorded in the Burma Forest Report for 1914-15, where it is stated that good natural reproduction resulted from the burning of an area in Toungoo in which the bamboo had flowered; this area had previously been fire-protected for many years.

A good instance of the value of loose soil was observed a few years ago in the Gonda district of the United Provinces, where vigorous seedlings appeared in large numbers in the loose earth washed down along the base of the ridge of earth thrown up alongside a new boundary trench. The abundance of the seedlings was due to the fruits having been washed against the base of the ridge and partially covered with soil, and indicates that surface water in the rains is an important distributing agency; the vigour of the seedlings was apparently due to the loose earth in which they grew. Similarly in loose bare earth along the sides of cart tracks in the forest seedlings are often found in great abundance.

The establishment of the pure type of *Terminalia tomentosa* forest on alluvial land in parts of the sub-Himalayan tract, which has already been alluded to, furnishes a good instance of a combination of factors which favour the reproduction of this species to such an extent that it becomes dominant, forming pure or almost pure forest. The chief factors in question are full overhead light, loose soil, sufficient soil moisture, and absence of dense weed-growth, though the ground may be covered with an open growth of moderately tall grass. The gradual evolution of this type of forest, which is illustrated in Figs. 197-200, is as follows :

The fruits are partly wind-borne and partly water-borne, and the seed germinates on alluvial deposits in the beds and along the banks of streams in a soil consisting of sand, or of fine sand with an admixture of clay forming a rich alluvial loam. Frequently *Acacia Catechu* and *Dalbergia Sissoo* are found coming up along with the *Terminalia*, the latter being mixed with the others either by single trees or, as is more common, by groups. In such a mixture the *Acacia* and *Dalbergia* eventually become outgrown and suppressed by the *Terminalia*, and the latter forms a pure crop or, if there are gaps in the crop, other species may come in; of these the commonest is *Anogeissus latifolia*, while sal also tends to appear where the locality is suitable and the cover is not too dense.

The development of this forest is interesting as showing that *Terminalia tomentosa*, like *Acacia Catechu* and *Dalbergia Sissoo*, is capable of establishing itself on new alluvial ground on which sal is unable to establish itself owing to the fact that the soil moisture in the dry season of the year is insufficient to support it; in other words, *Terminalia tomentosa* is capable of establishing

Owing to the light requirements of the young plants, sowing and planting under cover should be avoided, such work being confined to open places or gaps of some extent. Plantations are apt to be damaged by deer and pigs.

SILVICULTURAL TREATMENT. The correct treatment of this tree must be based on its light-demanding character during all stages of its existence. Actually its treatment is as a rule that of an accessory species to more valuable trees such as teak or sal, or as a component of a mixed crop in which it is not of outstanding importance. Under existing working plans it is worked along with other species usually under some form of selection felling or under coppice-with-standards. For the rearing of silkworms it is regularly pollarded. It is quite suitable for working as even-aged high forest with natural or artificial reproduction.

RATE OF GROWTH. (1) *High forest.* The annual rings are not always clearly distinguishable, though the rate of growth in several working plans is based on the results of ring-countings; the figures deduced in this way may be taken as only approximately correct. The results of various sample plot measurements are available, and these may be taken to be more accurate than the figures based on ring-countings, though here also there is an element of uncertainty in the fact that the time required for a seedling to establish itself under different conditions is not known.

United Provinces. The statement below gives a summary of the results of sample plot girth measurements in natural forest up to 1917, the measurements in all sample plots being combined for separate localities or forest divisions. These sample plots are situated in sal forest.

Terminalia tomentosa : girth increment in high forest sample plots,
United Provinces.

Age.	Corresponding girth.											
	Dehra Dun. (280 trees)		S. Kheri. (87 trees)		N. Kheri. (30 trees)		Gonda. (64 trees)		Pilibhit. (21 trees)		Bahraich. (30 trees)	
years.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.
10	..		0	..	0	..	0	..	..		0	5
20	..		0	5	0	7	0	4	..		0	10
30	0	11	0	10	1	1	0	7	..		1	5
40	1	4	1	2	1	8	0	11	2	0	2	0
50	1	10	1	6	2	2	1	4	2	6	2	7
60	2	3	1	11	2	8	1	8	2	11		
70	2	9	2	4	3	2	2	0	3	3		
80	3	4	2	10	3	7	2	4	3	7		
90	3	11	3	4	4	0	2	9	3	11		
100	4	6	3	10	4	4	3	1	4	2		
110	5	2	4	5	4	8	3	6				
120	5	9	5	1	4	11	3	10				
130	..		..		5	2	4	3				
140					5	4	4	9				
150					5	6	5	4				
160					5	8	5	11				
170					5	10	..					
180					5	11	..					

Note.—Measurements taken over bark at $4\frac{1}{2}$ ft. from ground-level: no addition made for time required for seedling to establish itself.

Bihar and Orissa. The following are the results of measurements in two sample plots in the Singhbhum forest division, (1) in Tirilposi block, (2) on the Samta-Hendakuli old road :

Terminalia tomentosa : girth increment in high forest sample plots, Singhbhum division.

Girth class.	No. of trees under observation.		No. of years under observation.		Mean annual girth increment for period.	
	(1)	(2)	(1)	(2)	(1) in.	(2) in.
ft.						
2-3	1	..	18	27	0.47	..
3-4	6	18			0.51	0.30
4-5	..	..			..	..
5-6	..	3			..	0.33
6-7	..	1			..	0.37

A tree raised from seed sown in 1901 by Mr. Haines in the forest garden at Chaibassa attained in sixteen years a height of 33 ft. and a girth of 2 ft. 3½ in.

Central Provinces. Ring-countings in the case of a few felled trees in the South Chanda forest division gave the following results : ¹

Terminalia tomentosa : girth increment, South Chanda, Central Provinces.

Girth at 4½ ft. from ground-level.	Age.	Mean annual girth increment.
in.	years.	in.
6	8½	0.71
12	17	0.70
18	25½	0.71
24	47	0.51
30	76	0.40

Note.—No addition made for time required for establishment of seedling.

The following results of sample plot measurements extending over a period of eight years in respect of 39 trees in the Baihar and Raigarh ranges of the Balaghat division show a very slow rate of growth : ²

Terminalia tomentosa : girth increment in high forest sample plots, Balaghat.

Age.	Mean girth.		Age.	Mean girth.		Age.	Mean girth.	
years.	ft.	in.	years.	ft.	in.	years.	ft.	in.
20	0	3½	70	1	5½	120	2	6½
30	0	6	80	1	8	130	2	9½
40	0	9	90	1	10½	140	3	0
50	1	0	100	2	1½			
60	1	2½	110	2	4			

Note.—No addition made for time required for establishment of seedling.

¹ Working Plan for the Dhaba, Ghot, and Markhanda Ranges and Elchil Forest, South Chanda, J. Donald, 1913.

² Statistics compiled in the Silviculturist's office, 1916-17; Ind. For. Rec., vol. vi, pt. v.

Bombay. The following table has been compiled from measurements based on ring-countings and recorded in high forest working plans in Bombay :

Terminalia tomentosa : diameter increment in high forest, Bombay Presidency.

North Kanara district.							Surat district.	
Age.	Supa fuel reserves, ¹ (1906)	Ankola high forest, Blocks xxiv and xxv, ² (1908)	Kalinaddi slopes, Block xxvi, ³ (1909)	Sopin hosalli high forest, Block xxvii, ³ (1910)	Ankola-Kumta coast, ³ (1911)	Sirai town forests, ³ (1913)	Ye[m]bi-Sonda forest, Block xxviii, ³ (1914)	North Dangs forests, ⁴ (1912)
years.	in.	in.	in.	in.	in.	in.	in.	
10	2.21	2.18	2.4	1.7	1.6	1.1	1.0	
20	4.20	4.00	5.7	3.7	4.0	2.4	2.6	
30	6.27	5.76	8.4	5.2	6.4	3.7	4.6	
40	8.12	7.46	9.9	6.8	8.6	5.0	6.6	
50	10.06	9.05	12.2	8.4	10.3	6.2	8.8	
60	11.50	10.55	14.2	10.0	11.8	7.4	10.7	
70	..	11.73	15.9	11.6	13.1	8.7	12.5	
80	..	12.80	17.6	13.1	14.3	10.1	14.3	
90	..	14.13	18.9	14.5	..	11.5	16.0	
100	..	15.51	20.4	15.8	..	13.0	17.6	
110	..	16.82	21.9	17.1	..	14.4	19.2	
120	..	18.10	23.2	18.5	..	15.6	20.6	
130	..	19.21	24.4	19.9	..	16.6	21.8	
140	..	20.75	25.5	21.3	..	17.6	22.8	
150	..	21.96	26.5	22.7	..	18.0	23.6	
160	..	23.10	27.3	24.0	..	..	24.4	
170	..	..	..	..	..	..	25.4	

Note.—Measurements do not include bark. Thickness of bark is given as 1.3 in. in the North Dangs forests, and 1.6 in. in the Sopin hosalli and Yekambi-Sonda forests.

¹ Measurements by D. A. Thomson.

² Measurements by R. S. Pearson.

³ Measurements by P. E. Aitchison.

⁴ Measurements by G. E. Marjoribanks.

Madras. Ring-countings in the Begur forest (25 trees) and Chedleth range forests (77 trees), North Malabar, gave the following results :

Terminalia tomentosa : results of ring-countings, North Malabar, Madras.

Diameter. in.	Corresponding girth. in.	Mean age.	
		Begur. years.	Chedleth range. years.
6	19	28	26
12	38	58	48
18	57	85	72
24	75	117	100

(2) *Coppice. United Provinces.* Measurements by Mr. C. M. McCrie in 1910 in sal coppice coupes at Ramgarh in the Gorakhpur district gave the following results for *Terminalia tomentosa* as compared with sal (*Shorea robusta*) :

Terminalia tomentosa : growth of coppice at Ramgarh, Gorakhpur, United Provinces.

Age. years.	Mean height.	Sal.	Mean girth.	Sal.
	<i>Terminalia tomentosa</i> . ft.		<i>Terminalia tomentosa</i> . in.	
2	4.5	3.0	1.3	—
4	9.0	7.0	3.0	2.0
6	12.3	10.3	4.5	2.9
8	15.0	13.0	5.7	3.8
10	17.0	15.3	7.3	4.8

The following measurements made by me in 1911 in young coppice coupes in the Tikri forest, Gonda, show the comparative growth of *Terminalia tomentosa* and sal :

Terminalia tomentosa : growth of young coppice in the Tikri forest, Gonda, United Provinces.

Age. years.	Mean height.	Sal.	Average No. of shoots per stool.	Sal.
	<i>Terminalia tomentosa</i> . ft.		<i>Terminalia tomentosa</i> . in.	
1	8.2	4.7	4.7	2.2
2	11.2	10.0	2.9	1.7
2	6.3	7.6	4.7	1.8

Bihar and Orissa. Measurements in coppice coupes of various ages in the Saitba block, Kolhan, Chota Nagpur, in a somewhat dry type of forest on hilly ground with stony soil, gave the following results :

Terminalia tomentosa : growth of coppice in the Saitba block, Kolhan, Chota Nagpur.

Age. years.	Mean height.	Sal.	Mean girth.	Sal.
	<i>Terminalia tomentosa</i> . ft.		<i>Terminalia tomentosa</i> . in.	
2	5.5	9.0	1.5	4.0
4	10.5	16.0	3.2	6.5
6	14.5	20.0	4.8	8.6
8	17.8	22.5	6.5	10.3
10	20.4	24.5	8.3	11.5
12	22.7	26.5	10.0	12.6
14	24.5	28.5	11.6	13.6

Bombay. The following coppice measurements are recorded in the working plan for the Karwar fuel reserves, West Kanara forest division : ¹

Terminalia tomentosa : growth of coppice in the Karwar fuel reserves, West Kanara, Bombay.

Age.	Girth.	Age.	Girth.
years.	in.	years.	in.
4	6.75	11	11.16
5	8.46	12	11.31
6	8.55	13	11.69
7	8.71	15	12.75
8	9.26	18	17.0
9	10.55		

¹ Working Plan for the Karwar Fuel Reserves, West Kanara, Bombay, D. A. Thomson, 1904.
2307.2

4. *Terminalia Arjuna*, Bedd. Syn. *T. glabra*, W. and A.; *Pentaptera Arjuna*, Roxb. Vern. *Arjún*, *arjuna*, *kahua*, *koha*, Hind.; *Savimadat*, Mar.; *Holematti*, Kan.; *Kula maruthu*, Tam.; *Thella maddi*, Tel. (Fig. 204.)

A large handsome tree, evergreen or nearly so, with trunk often buttressed, a large crown and drooping branchlets. Bark smooth, exfoliating in thin irregular sheets, green when newly exposed, turning light grey, pink inside; young bark with chlorophyll. The tree resembles *T. tomentosa* except for its smooth bark, the narrower wings to the fruits, and the fact that it is characteristic of the banks of streams. It sometimes attains an enormous girth. Mr. J. C. McDonnell¹ records two trees 26 ft. and 32 ft. in girth at 5 ft. from ground-level at the village of Manapur in Jammu.

The wood is brown, very hard, used for building, agricultural implements, carts, and boats. The bark is used for tanning, and is much collected for the purpose in Central India. A special blazing instrument is used which strips off flakes of cortex without penetrating to and damaging the cambium, and within two years the stripped patches are covered with a thick new growth of cortex slightly lighter in colour than the original bark: if the cambium is injured the wood blackens and no regrowth of cortex takes place.

DISTRIBUTION AND HABITAT. *Terminalia Arjuna* is common throughout the greater part of the Indian Peninsula along rivers, streams, ravines, and dry watercourses, reaching a large size on fertile alluvial loam. It extends northward to the sub-Himalayan tract, where it is locally distributed along the banks of streams. It is common in Chota Nagpur, Central India, the Central Provinces, and parts of the Bombay and Madras Presidencies, extending south to Ceylon. It is often planted for shade or ornament along roadsides and in avenues. In some localities it has escaped from cultivation along streams, and is doubtfully indigenous. It is found naturally in regions where the absolute maximum shade temperature varies from 100° to 118° F., the absolute minimum from 30° to 60° F., and the normal rainfall from 30 to 70 in.; as, however, its occurrence depends largely on the moisture supplied by streams, its distribution is not governed by climatic considerations alone.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The tree is evergreen or nearly so, the new foliage appearing early in the hot season. The panicked spikes of small white flowers appear from April to July, and the fruits ripen the following February to May. The fruits (Fig. 202, a) are 1–2 in. long, with a hard bony axis and five to seven wings 0.25–0.5 in. broad; about 80–110 weigh 1 lb. As in *T. tomentosa*, the germinative power of the seed is often indifferent. The tree flowers and fruits at an early age: a tree six years old flowered and fruited abundantly at Dehra Dun in 1918.

GERMINATION (Fig. 202, b–f). Epigeous. The hard endocarp of the fruit opens slightly and the radicle emerges. The hypocotyl elongates by arching, and the large foliaceous cotyledons, which are convolute in the seed, extricate themselves and unroll. The hypocotyl straightens and still farther elongates, carrying the cotyledons above ground; at the same time the young shoot emerges from between the two cotyledonary petioles.

¹ Ind. Forester, xxix (1903), p. 152.

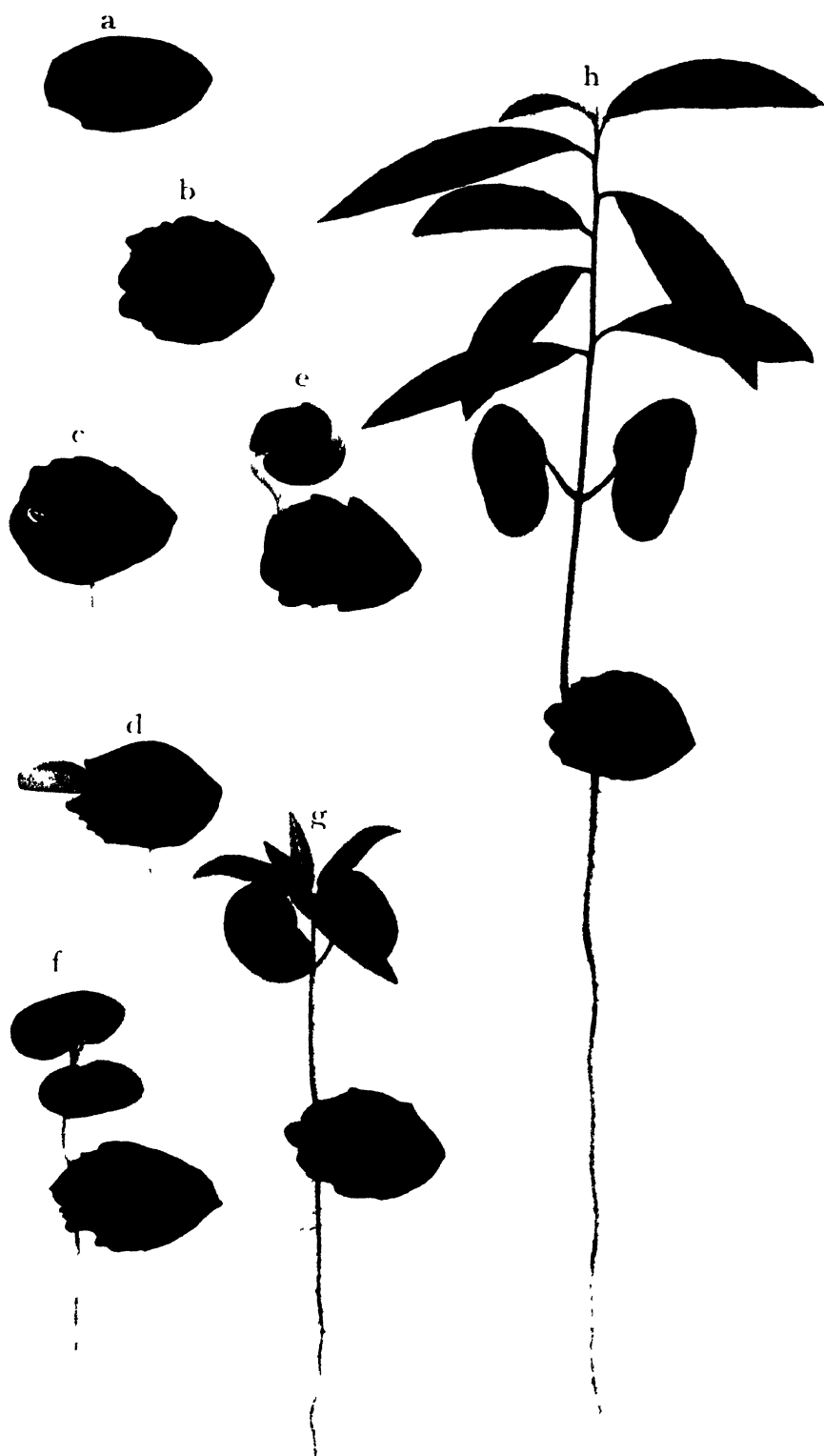


FIG. 202. *Terminalia Arjuna* -SEEDLING $\times \frac{2}{3}$

a—Fruit b - f—Germination stages g, h— Development of seedling to end of first season

THE SEEDLING (Fig. 202).

Roots : primary root long, terete, tapering, wiry : lateral roots numerous, fibrous, distributed down main root. **Hypocotyl** distinct from root, 2·2–3 in. long, terete or slightly compressed, tapering slightly upwards, tomentose. **Cotyledons** : petiole 0·3–0·6 in. long, flattened above, tomentose : lamina 0·7–0·9 in. by 1·4–2·2 in., foliaceous, somewhat fleshy, reniform, much broader than long, apex broadly truncate, base decurrent, entire, green, with three conspicuous and two minor veins from the base. **Stem** erect, terete, pubescent ; first internode, above the cotyledons, 1·8–2·2 in., subsequent internodes 0·2–1 in. long. **Leaves** simple, alternate, or first pair sub-opposite, exstipulate. Petiole 0·2–0·3 in. long, flattened above, pubescent. Lamina 2·4–4 in. long, elliptical lanceolate, apex and base acute, widely serrulate, sparsely pubescent, or glabrous on the upper surface, venation sub-arcuate, lateral veins 8–12 pairs.

The young seedling of this species is easily distinguished from those of *T. tomentosa* and *T. Chebula* by the length of the hypocotyl and cotyledonary petioles (see p. 519).

The growth of the seedling during the first season is somewhat faster than in the case of *T. tomentosa*, a height of about 5–12 in. being ordinarily attained under natural conditions, and a height of 1 ft. to 1 ft. 9 in. in the case of nursery-raised plants. A fairly long taproot is developed early and may attain a length of as much as 1 ft. within two months of germination. As in the case of *T. tomentosa* and *T. myriocarpa*, the young plant during the first few years tends to assume a straggling or branching formation, sacrificing height-growth to the production of long side branches which bend over towards the ground. This does not always occur, however, and rapid height-growth may take place from the commencement ; thus young tended plants at Dehra Dun have attained a height of 6–10 ft., with a basal girth of 5–8 in., in three years. In Berar seedlings have reached a height of 1½ ft. in two years, and at Nagpur they have attained 3 ft. in 2½ years. Growth is stimulated by regular watering and loosening of the soil.

The seedlings are somewhat sensitive to frost, and are decidedly sensitive to drought, both in the germinating stages and subsequently. They grow well in full sunlight provided the ground is moist ; they also stand moderate shade, but not dense overhead shade. In northern India the season's growth ceases in November–December and new growth commences about March.

SILVICULTURAL CHARACTERS. The tree is capable of standing more shade than *T. tomentosa*. It has a more or less superficial root-system, and relies for its moisture chiefly on the streams whose banks it frequents. It is somewhat tender to frost as well as to drought. Mr. C. M. McCrie¹ notes regarding the abnormal drought of 1899 and 1900 that many trees along the banks of the streams in the Nagpur district died owing to the lowering of the subsoil water-level. The tree produces root-suckers and pollards well. Experiments in Bombay have shown that it coppices well up to a girth of about 2½ ft., after which the coppicing power is indifferent.

NATURAL REPRODUCTION. Under natural conditions germination takes place early in the rainy season, and may actually commence with the early showers before the monsoon proper. Numerous experiments at Dehra Dun,

¹ Ind. Forester, xxvi (1900), p. 338.

including plots of ground kept moist by percolation in order to imitate natural conditions, showed that the seed does not germinate readily if exposed to the sun, and if germination begins the radicle is very liable to dry up. If the fruits become partially buried by rain or otherwise germination is much more successful, while the success is greater on bare soil with a considerable amount of moisture, provided the fruits are buried : these conditions ordinarily obtain on alluvial ground along streams. A certain degree of shade, particularly from the side, assists the establishment of the seedling, but heavy shade is inimical. In the forest seedlings are often to be found in large quantities where the fruits have been accumulated by the action of streams in loose alluvial soil and conditions for germination have been favourable.

ARTIFICIAL REPRODUCTION. The plants bear transplanting well during the first rainy season before the taproot becomes too long. The fruits should be sown in the nursery about April–May, covered lightly, and watered regularly. Irrigated weeded line sowings have been found successful.

RATE OF GROWTH. Few detailed statistics are available regarding the rate of growth, but young trees planted at Dehra Dun and well watered have grown fairly rapidly. A cross-section from the United Provinces 2 ft. 8½ in. in girth, including bark, in the silvicultural museum at Dehra Dun showed 43 rings, giving a mean annual girth increment of 0.75 in. Trees raised from seed sown in 1901 by Mr. Haines in the forest garden at Chaibassa, Chota Nagpur, attained the following dimensions in sixteen years :

- (1) Height 40 ft., girth 2 ft. 11 in.
- (2) Height 37 ft., girth 2 ft. 8 in.
- (3) Height 37 ft., girth 1 ft. 8½ in.

Measurements in coppice coupes in Bombay showed that a height of 12 ft. and a girth of 10 in. may be expected in six to seven years.

5. *Terminalia myriocarpa*, Heurck and Muell. Arg. Vern. *Panisaj*, Nep. ; *Hollock*, *jhalna*, Ass.

A very large evergreen tree with pendulous branches. Bark greyish brown, rough, exfoliating in vertical flakes. Wood dark brown, hard, used for house-building, canoes, cheap furniture, and other purposes. The tree attains very large dimensions. Mr. Jacob¹ records one tree in the Raidak valley over 30 ft. in girth, and two trees close together in the Chirrang valley roughly 36 and 27 ft. in girth. Babu R. N. De² records a tree 46 ft. 4 in. in girth round buttresses in the Lakhimpur district, Assam.

DISTRIBUTION AND HABITAT. Eastern Himalaya from Nepal eastwards, in valleys and lower hills up to 5,000 ft., Assam, hills of Upper Burma. It is very plentiful in some localities, often coming up in gregarious patches on newly exposed ground, forming pure even-aged groups underneath which evergreen species appear. Mr. Jacob notes that it is very common in Bhutan up to 3,000 ft. and is found up to 4,000 ft. Mr. Milroy³ reports that in the Abor country it is the predominant tree on the lower hills, where trees of 12 and 14 ft. girth are common, and still larger ones up to 18 and 20 ft. are not scarce ; he adds that although the trees are apt to be short in the bole

¹ Report on the Forests of Bhutan, 1912.

² Ind. Forester, xlv (1918), p. 517.

³ Report on the Forest Resources of the Abor Country, 1912.

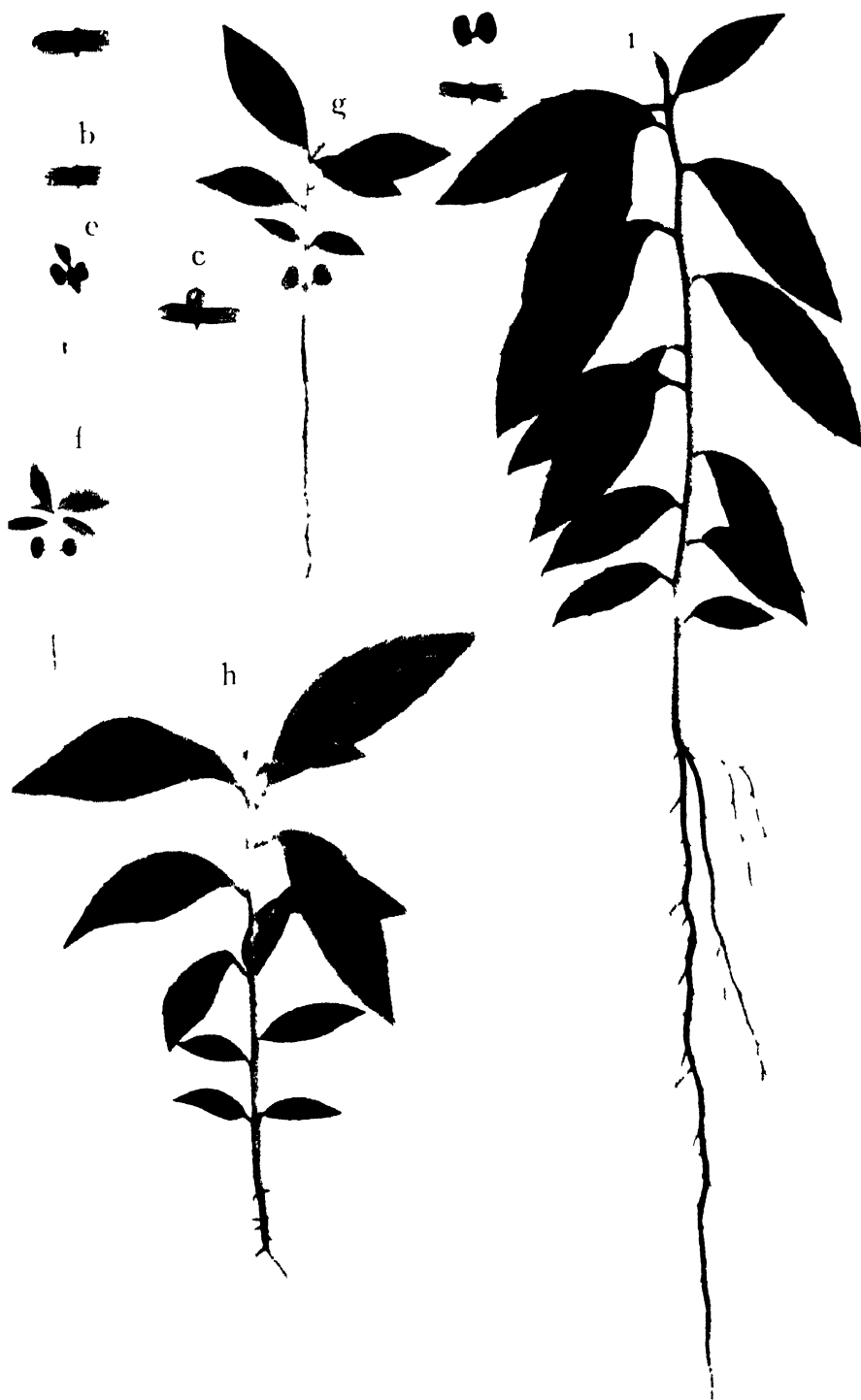


FIG. 203. *Terminalia myriocarpa* SEEDLING $\times \frac{1}{2}$

a—Fruit b d—Germination stages e 1 Development of seedling to end of first season

and much branched a great quantity of clean timber could be extracted from them.

Terminalia myriocarpa is essentially a tree of moist situations and rich soil, and in Assam is often found associated with *Bischofia javanica*. In its natural habitat the absolute maximum shade temperature varies from 90° to 102° F., the absolute minimum from 33° to 45° F., and the normal rainfall from 80 to 200 in. or possibly more.

FLOWERING AND FRUITING. The panicles of small pink flowers appear in October–November and the fruits ripen from March to June. The fruits (Fig. 203, *a*) are small and light, 0.1–0.15 in. long, light yellowish brown, with a pair of lateral membranous wings, the whole 0.4–0.5 in. in width. About 4,000 to 4,500 weigh 1 oz. The germinative power of the seed is fairly good, tests at Dehra Dun showing a fertility of 63 per cent., which for a small light seed is not unsatisfactory. Seed-year records show that the tree seeds well as a rule every year. The trees are a very handsome sight when covered with masses of pink blossom or yellow fruits.

GERMINATION (Fig. 203, *b–d*). Epigeous. The thin radicle emerges from one end of the winged fruit and the cotyledons from the other; the hypocotyl quickly elongates, carrying above ground the cotyledons, which expand in the meantime, and the young shoot emerges from between them.

THE SEEDLING (Fig. 203).

Roots: primary root moderately long, terete, tapering, wiry; lateral roots numerous, fine, fibrous, distributed down main root. **Hypocotyl** distinct from root, 0.5–0.8 in. long, thin, terete, cylindrical, tomentose. **Cotyledons**: petiole 0.1–0.15 in. long, flattened above, pubescent; lamina 0.1–0.2 in. by 0.15–0.3 in., foliaceous, reniform or sub-orbicular, broader than long, apex truncate or retuse, base tapering, entire, glabrous or minutely pubescent. **Stem** erect, terete, green or red, rusty tomentose; internodes 0.2–0.7 in. long. **Leaves**, first pair opposite, small, subsequent leaves larger than first pair, alternate, exstipulate. First pair with petiole 0.1 in. long or less, tomentose, lamina 0.4–0.5 in. by 0.15–0.2 in., elliptical lanceolate, apex and base acute, entire or obscurely serrate, glabrous or sparsely pubescent above, sparsely pubescent beneath. Subsequent leaves with petiole 0.1–0.3 in. long, tomentose, lamina 0.1–2.8 in. by 0.4–1 in., elliptical lanceolate, acuminate, base acute, serrate, pubescent, venation arcuate, lateral veins 6–10 pairs, nearly reaching the margin; later leaves of the first season with glands at the base. The serrate leaves of the seedling are interesting; the adult leaves of this species, and of the whole order, are entire.

In its early stages the seedling is minute, and is apt to be washed away by rain before it gains a footing. It develops rapidly, however, and attains a height of about 4–8 in. or more by the end of the first season. As in the case of *T. tomentosa* and *T. Arjuna*, the young plant has a tendency to produce long straggling branches in place of a definite leader, but in spite of this its height-growth after the first season is rapid. Sixteen plants grown at Dehra Dun had a height of 4 ft. 8 in. to 7 ft. 3 in. by the end of the second season, and 10 to 15 ft. by the end of the third season.

SILVICULTURAL CHARACTERS. The tree bears a fair amount of shade and is exacting as regards moisture. It is not known to produce root-suckers.

NATURAL REPRODUCTION. The ideal conditions for successful reproduction are a loose porous soil free from weeds, in order to enable the small light

fruit to reach the soil and the germinating seedling to establish itself quickly, and a fair amount of soil moisture. The light fruits tend to be washed into heaps and the minute seedlings are also liable to be washed away, considerable mortality resulting. The young seedlings are apt to dry up if exposed to the sun, and benefit by a certain amount of shade; they are also apt to die off in quantity on stiff water-logged soil, and good drainage appears to be necessary for their establishment. The young crop often tends to come up gregariously, where conditions are favourable, on newly exposed ground or fresh alluvium.

ARTIFICIAL REPRODUCTION. Direct sowings are unsuitable, as the small light fruits are liable to be washed away. Experiments at Dehra Dun showed that the best results are attained in fine porous sandy soil in boxes or in well-raised beds protected from sun and heavy rain; watering should be frequent but light. Germination ordinarily starts in two or three weeks and may continue for about three months. The plants transplant well during the first rainy season when 3 to 4 in. high.

6. Terminalia Catappa, Linn. Syn. *T. procera*, Roxb. Indian almond. Vern. *Badam*, Beng. Known in the Andamans as 'white bombway', a corruption of the Burmese *banbwè* (*Careya arborea*).

A large handsome deciduous tree with whorled branches and large glabrous leaves which turn red before falling in the hot season. Bark smooth, grey, stem often buttressed. The tree is a native of the Andamans and adjacent islands and of the Malay Peninsula, in coast forests. It is extensively planted in tropical India and in Burma, particularly round monasteries, both for ornament and for the sake of its fruits, the kernels of which are eaten.

In the Andamans it is common in the littoral forests on raised beaches and deposits of sea-sand above high tide, associated with *Calophyllum Inophyllum*, *Azelia bijuga*, *Thespesia populnea*, *Heritiera littoralis*, *Erythrina indica*, *Sterculia* spp., *Pongamia glabra*, *Odina Wodier*, *Hibiscus tiliaceus*, and *Pandanus tectorius*. It also extends into the padauk forests, where it is confined to sandy soil as a rule not far from the sea, or to diluvial deposits formed of detritus brought down by streams in flood.

The whitish flowers, in axillary spikes, appear from February to May, and according to Bourdillon again in October–November (Travancore). The fruits ripen in June–July (also January, Bourdillon). The fruit is a yellowish ellipsoidal drupe, somewhat compressed, 1.5–2 in. long, with a porous fibrous to fleshy pericarp and a hard endocarp enclosing the edible seed. The fruit is adapted for dissemination by water, the thick husk of porous tissue rendering it buoyant. The tree is easily raised from seed, the fruits being sown in the nursery about July and the seedlings transplanted during the following rainy season. The tree grows best in a moist tropical climate.

7. Terminalia paniculata, Roth. Vern. *Kindal*, *kinjal*, Mar.; *Hulve*, *honal*, *bili-matti*, Kan.; *Pulavdi*, *venmarudu*, *pumarudu*, Tam.; *Nimiri*, *pula-maddi*, Tel.

A large to very large deciduous tree. Bark 0.4–0.6 in. thick, dark brown, rough, with numerous shallow longitudinal and transverse fissures. The lower part of the bole is often much fluted. Heartwood light brown, very hard; wood used chiefly for planking, agricultural implements, and canoes, but not

quite so much in demand as that of *T. tomentosa*. The bark contains much tannin.

The tree reaches considerable dimensions. Mr. H. Tireman records one 13 ft. 3 in. in girth measured in the Coorg forests: large trees, however, are usually unsound inside. It attains a height of 100 ft. under favourable conditions.

DISTRIBUTION AND HABITAT. The tree is found in the western regions of the Indian Peninsula from Bombay southwards, and in southern India. In Bombay it is one of the commonest trees of the North Kanara mixed deciduous forests, its most important associates being teak, *Dalbergia latifolia*, *Pterocarpus Marsupium*, *Terminalia tomentosa*, *Lagerstroemia lanceolata*, and *Xylia xylocarpa*. It is rare on the Deccan trap and absent from the Dangs and Satpuras. It extends southwards through South Canara and Malabar to Travancore, and occurs in the Nilgiris, Anamalais, and other hill ranges of southern India. In Coorg it is most plentiful and attains its largest dimensions in the deciduous forests of the *ghats*; it is also found throughout the eastern forests, but here it reaches smaller dimensions. Throughout its region it is often the most plentiful species of the mixed forests. Bourdillon says it is probably the commonest tree in Travancore, often forming 50–60 per cent. of the trees in the deciduous forests up to 2,000 ft. elevation. It is also the commonest timber tree of the Nilambur valley in Malabar and of some of the Kanara forests.

The tree is most frequently found in valleys and on lower slopes, preferring fairly moist situations. It requires a well-drained soil, and is not found on water-logged ground, thus differing from *T. tomentosa*. In the Western Ghats it grows equally well on the laterite soils at the foot of the *ghats* and on the decomposed crystalline rocks of the slopes.

In its natural habitat the absolute maximum shade temperature varies from 95° to 102° F., the absolute minimum from 55° to 65° F., and the normal rainfall from 40 to 180 in. or more.

FLOWERING AND FRUITING. The flowering season appears to vary. Brandis gives it as August to December, Talbot (Bombay) as August to September, and Bourdillon (Travancore) as July to December, one flowering succeeding another. Mr. H. Tireman informs me that in 'Coorg he has observed it in flower in April–May. The flowers are small and white in rusty-pubescent paniced spikes.

The fruits, which ripen from December to May, are brick-red, 0.25–0.5 in. long, with one large wing about 0.5–0.75 in. broad and two smaller wings; about 100–120 fruits weigh 1 oz.

SILVICULTURAL CHARACTERS. The tree stands rather more shade than *T. tomentosa*, saplings and poles being found coming up in small gaps; it will not, however, stand heavy shade, and may be regarded as a light-demander rather than a shade-bearer. Frost is unknown within its region, and prolonged drought seldom if ever occurs. The tree coppices well up to a moderate size.

NATURAL REPRODUCTION. The natural reproduction of this tree is as a rule plentiful, though the conditions influencing it require further study. In many places the moist deciduous forests of Kanara are gradually changing towards the evergreen type as a result of fire-protection, and the natural

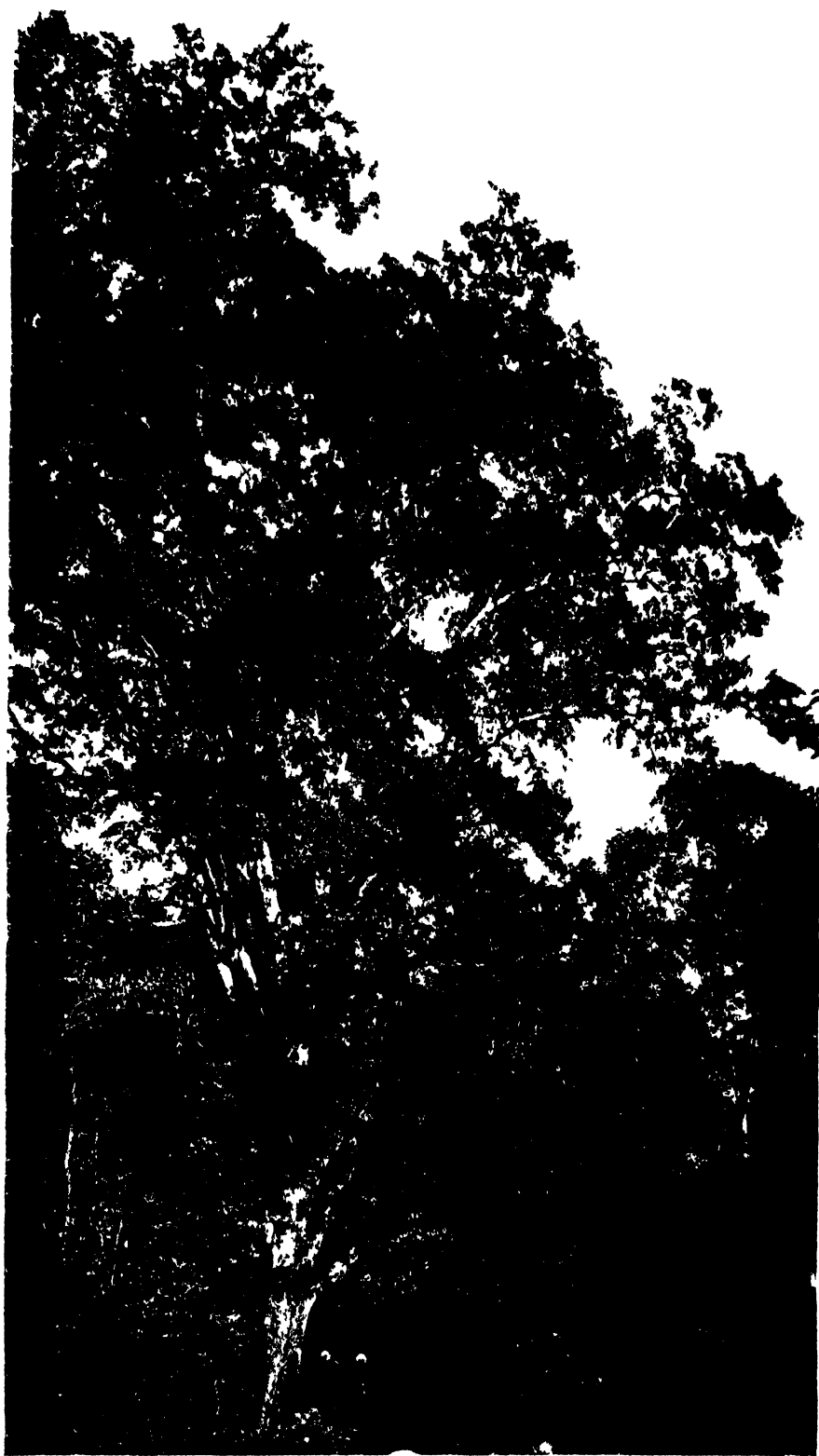


FIG. 205 *Anogeissus latifolia*, Dehra Dun, United Provinces.

8. *Terminalia bialata*, Steudel. White chuglam (Andamans). Vern. *Lein*, Burm.; *Chugalam*, And.

A large deciduous tree of Burma and the Andamans, reaching a height of 100 ft. In Burma it occurs in the upper mixed deciduous forests along with teak and its associates, and probably also in the lower mixed forests. In the Andamans it is one of the chief species in the semi-deciduous forests associated with *Pterocarpus dalbergioides* (padauk), *Lagerstroemia hypoleuca*, *Bombax insigne*, *Sterculia* spp., *Albizia Lebbek*, and others. It also occurs sometimes in the evergreen dipterocarp forest. It flowers in the rainy season (Brandis) and the fruits ripen in the cold season (Kurz); ripe fruits have been received from Burma in February. Mr. C. G. Rogers¹ says that numbers of germinating seeds were seen in the Andaman forests in the month of May, and that the large proportion of this species, including saplings and poles, in the standing crop points to its being better able to reproduce itself naturally than the other trees associated with padauk. The wood of this tree is strong, elastic, straight grained, and of good quality, and it is likely to become an important timber when better known.

Another tree known in Burma as *lein* is common on the plains of Pegu, where it is of comparatively small size with a bushy form of growth. This is probably *T. pyrifolia*, Kurz, which, according to Brandis, merits careful study in the forest, as to whether it is really a distinct species; its size and mode of growth are certainly different from that of the larger and cleaner-stemmed *T. bialata*.

9. *Terminalia Oliveri*, Brandis. Vern. *Than*, Burm.

A moderate-sized deciduous tree with smooth greenish grey bark and a somewhat irregularly shaped and often channelled stem. It attains a height of 40–50 ft. and a girth of 4–5 ft., but on poor ground it is stunted. The leaves are only 1.5–3 in. long, and turn red before falling in the hot season. The fruit is five-winged like that of *T. tomentosa*, but much smaller. The wood is a good fuel and the bark is illicitly used to adulterate cutch. This tree is very common in the dry zone of Upper Burma in tracts where the rainfall varies from 22 to 40 in. and the soil is often poor and shallow. It extends from the Magwe and Yamethin districts in the south to about 23½° N. lat. in the Ruby Mines district in the north. It is one of the most characteristic trees of the dry open forests associated with *Acacia Catechu*, *A. leucophloea*, *Tectona Hamiltoniana*, *Diospyros burmanica*, *Terminalia tomentosa*, *Pentacme suavis*, and other species. Towards its northern limit in the Ruby Mines district it occurs in dry open forest on poor shallow soil, its chief associates being *Diospyros burmanica*, *Vitex pubescens*, *Pterocarpus macrocarpus*, *Anogeissus acuminata*, *Xylia dolabriformis*, *Terminalia tomentosa*, *Acacia Catechu*, and others, with bamboos, chiefly *Dendrocalamus strictus*: the trees are of small size. Towards its southern limit in the Magwe and Yamethin districts it occurs in dry forest of a similar type, which may be regarded as a transition between the scrub forests of the dry zone and the upper mixed deciduous forests occurring outside that zone.

¹ Report on the Exploration of the Forests of the South Andaman and other Islands, 1906, para. 23.

2. ANOGEISSUS, Wall.

This genus contains three well-defined Indian species ; *A. sericea*, Brandis, which occurs in parts of the Central Provinces and in the Panch Mahals, is possibly not distinct from *A. acuminata*, Wall. The fruit is small, dry, two-winged, terminating in a beak formed by the persistent calyx-tube ; the fruits are clustered in small globose heads. One of the chief peculiarities of this genus is the infertility of the seed, in spite of which natural reproduction often appears in great quantity, resulting in the case of *A. latifolia* and *A. pendula* in gregariousness. This question is discussed in dealing with *A. latifolia* ; it has been suggested that fertile seed is produced in quantity only in certain years, and that the cause of this is climatic.

Species 1. *A. latifolia*, Wall. ; 2. *A. pendula*, Edgw. ; 3. *A. acuminata*, Wall.

1. *Anogeissus latifolia*, Wall. Syn. *Conocarpus latifolia*, DC. Vern. *Dhaura*, *dhau*, *dhawa*, *bákli*, Hind. ; *Dindal*, *dinduga*, Kan. ; *Vellay naga*, Tam. ; *Chiriman*, Tel. (Fig. 205.)

A moderate-sized to large deciduous tree with a somewhat feathery rounded crown and drooping branchlets. Bark thin, smooth, greenish or greyish white, exfoliating in irregular thin rounded scales which leave shallow depressions ; the outer layer contains chlorophyll. The bark sheds rapidly, and rings of paint often disappear within two or three years of being applied.

The tree seldom attains very large dimensions, a girth of more than 6 ft. not being common. Mr. T. Carr recorded a sound tree 9 ft. 3 in. in girth in the Sarda range of the Haldwani forest division, United Provinces. A cross-section without bark in the silvicultural museum at Dehra Dun measures 8 ft. 9 in. in circumference ; this was cut from a tree in the United Provinces.

The wood, which is hard, very strong, and tough, is used for cart-axles, shoulder-poles, axe-handles, furniture, agricultural implements, poles and rafters, boat-building, and other purposes. The leaves are rich in tannin, and are collected for tanning purposes ; the bark is also used for tanning, and yields a gum much used in calico-printing. Apart from its economic uses the tree is useful silviculturally in clothing dry hill-sides, and is an important constituent in certain dry types of forest.

DISTRIBUTION AND HABITAT. Throughout the sub-Himalayan tract and outer hills from the Ravi to Nepal, ascending to 4,000 ft., Bihar, Chota Nagpur, Central India, and southwards throughout the greater part of the Indian Peninsula, ascending the hills of southern India to 4,000 ft. ; also in the dry country of Ceylon. Not in eastern Bengal, Assam, or Burma.

The tree is characteristic of deciduous forests, usually of a dry type, but is also common in sal forest and in other types of moderately moist forest. In the outer Himalaya it often marks a distinct zone towards the upper limit of the low-level species, at about 2,500–4,000 ft. ; here it is gregarious, forming almost pure crops or mixed with *Bauhinia retusa* and a few other species. In the Siwalik hills it occurs gregariously in the same way on sandstone and conglomerate, the chief species associated with it being *Buchanania latifolia*,

Ougeinia dalbergioides, *Terminalia tomentosa*, *Wendlandia exserta*, and *Pinus longifolia*. In the submontane forests of the Himalayan region it is often abundant, both in certain types of sal forest and in mixed forest without sal. A very common companion is *Terminalia tomentosa*, and on alluvial flats near streams the crop sometimes consists entirely of this species and *Anogeissus*; here the trees attain large dimensions.

In Chota Nagpur it is very common, especially on the drier hills, often growing more or less gregariously. In the hills of Central India it is likewise plentiful in some localities. In Gwalior it often forms an underwood in *Boswellia* forests. In the Central Provinces and Bombay it is a common constituent of the mixed deciduous forests, where it is at times gregarious, among its chief companions being teak, *Terminalia tomentosa*, *Lagerstroemia parviflora*, *Ougeinia dalbergioides*, *Diospyros Melanoxydon*, *Cassia Fistula*, and *Phyllanthus Emblica*.

In Bombay it is one of the commonest trees above *ghats*, particularly in Belgaum and Kanara; on the eastern (Dharwar) side of the North Kanara forest division it forms nearly pure crops over considerable areas. In the Madras Presidency it is perhaps more abundant than it is anywhere else, particularly in the south-east, in Madura and in Tinnevely, where it may form as much as 50 per cent. of the crop on the upper dry slopes of the hills. It is plentiful in the eastern forests of Coorg, in many parts of Mysore and Hyderabad, and in the dry deciduous forests of Travancore up to 4,000 ft.

Generally speaking it avoids moist regions, but on the other hand it does not extend into the driest parts of India, being absent from Sind and rare in Ajmer-Merwara: in the drier regions of its habitat it is usually stunted and crooked, though this condition is often due in part to fire and maltreatment. It grows on a variety of geological formations, including sandstone, limestone, metamorphic rocks, trap, and laterite: it attains its largest dimensions, however, on deep alluvial or diluvial soil. It avoids swampy and badly-drained ground, and requires good drainage. In the natural habitat of the tree the absolute maximum shade temperature varies from 102° to 118° F., the absolute minimum from 30° to 60° F., and the normal rainfall from 25 to 90 in.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The leaves turn a coppery red to reddish brown about November, and in the cold season the trees are very conspicuous with their deep red foliage. The leaves fall chiefly in February, the trees remaining leafless until April-May, when the new foliage appears. The insignificant greenish yellow flowers, in small globose heads, appear from June to September according to locality (August-September towards the northern limit of the species).

The small dry indehiscent fruits (Fig. 206, *a*), crowded in globose heads, are 0.15-0.25 in. in diameter, compressed, with a narrow wing on each side, yellowish brown, fairly hard. About 3,000-3,500 weigh 1 oz. They ripen from December to March, fall soon after ripening, and may be found scattered over the ground round the trees from February-March onwards.

As a rule the tree seeds abundantly every year, but the fertility of the seed is usually very poor; this question is considered under 'natural

reproduction'. Fertility tests can probably best be carried out on shaded well raised and watered beds of loose sand and gravel, as explained under 'artificial reproduction'.

GERMINATION (Fig. 206, *b*). Epigeous. The radicle emerges from the extremity of the fruit and descends. The hypocotyl and the cotyledonary petioles elongate, raising the cotyledons above ground. The shell of the fruit encloses the cotyledons for a time, falling with their expansion.

THE SEEDLING (Fig. 206).

Roots: primary root long, moderately thick, terete, tapering, woody or wiry; lateral roots few to moderate in number, short, fibrous, distributed down main root. **Hypocotyl** distinct from root, 0.1–0.3 in. long, terete or slightly compressed, minutely pubescent. **Cotyledons**: petiole 0.5–0.9 in. long, finely pubescent, often red; lamina 0.2–0.4 in. by 0.35–0.6 in., foliaceous, much broader than long, apex truncate or retuse, base tapering, entire, glabrous above, minutely pubescent beneath, green, often red beneath, prominently 3-veined from the base. **Stem** erect, terete, wiry, pubescent, often reddish; internodes 0.1–0.8 in. long. **Leaves**, first two sub-opposite or alternate, sometimes abortive and 0.1–0.2 in. long, subsequent normal leaves alternate, at first small, successively increasing in size. Stipules absent. Petiole up to 0.1 in. long. Lamina 0.4–2.8 in. by 0.3–1.1 in., elliptical ovate, acute or acuminate, mucronate, base acute, entire, glabrous above, glabrescent or minutely pubescent beneath, especially on the veins, margins finely ciliate, venation arched reticulate, veins often reddish on under surface.

The growth of the seedling is only moderate, a height of 4–8 in. being ordinarily attained by the end of the first season. The taproot attains a length of 18 in. or more in the same time. The seedlings suffer a little from frost, but the damage is not as a rule serious, and extends only to the wilting of the leaves. In dry localities the seedlings may die back annually for some years before they finally shoot up.

SILVICULTURAL CHARACTERS. The tree is a decided light-demander, though it can stand a slight amount of shade in early youth. Although it grows in dry types of forest it is sensitive to drought, and suffered much in the abnormal droughts of 1899–1900 in the Indian Peninsula and of 1907 and 1908 in Oudh: in the dry years from 1911 to 1914 in Jodhpur many young coppice-shoots died back and the stools did not recover. As regards its susceptibility to frost, Brandis notes that in January 1870, on the borders of Pertabgarh, south-west of Nimuch, he found it had been injured a good deal. It may, however, be found flourishing in grass-covered frosty blanks where tender species could not exist, for example on the flat land fringing the Siwalik hills along with other frost-hardy species such as *Stereospermum suaveolens*, *Ougeinia dalbergioides*, and *Acacia Catechu*. It cannot therefore be considered a very frost-tender species. It is less susceptible to damage by browsing than many other species, even goats being not very partial to it. It suffers from fire, and in severely burnt areas it becomes gnarled and hollow. It produces root-suckers. If cut at the right season of the year it coppices and pollards well in most localities, but in experiments carried out in North Chanda, Central Provinces, in 1909, of trees pollarded only 16 per cent. produced pollard-shoots, while in the case of trees coppiced in different months the percentage of stools which produced coppice-shoots was: (1) April, 92; (2) May, 100; (3) June, 50; (4) July, 50; (5) August, nil; (6) September, nil. This shows that coppicing



FIG. 206 *Anogeissus latifolia* SEEDLING $\times \frac{1}{8}$

a 1 rut

b—Germination

c g—Development of seedling during first season

the lantana, and the rapid growth of the seedlings, when the lantana is removed, is stimulated by the absence of grass for the first year or two and the fact that the lantana enriches the soil.

ARTIFICIAL REPRODUCTION. The fruits require to be collected when the heads commence to break up, and not before. The infertility of the seeds is a serious drawback to artificial reproduction, and if the theory just referred to holds good the best results would seem to be obtainable after dry years when a fertile crop of seed is obtained. Under ordinary conditions the infertility of the seed would preclude any great success by direct sowings, though in years of fertile seed-production they should prove successful on well-drained porous ground. Many years ago Mr. Haines carried out successful sowings on heaps of loose earth and rubble at Chaibassa, Chota Nagpur. Mr. Pearson¹ notes that he obtained successful germination in the Panch Mahals, Bombay, by sowing the seed on well-irrigated raised beds, the soil being mixed with a large quantity of coarse sand ; the seed was sown in June and lightly watered by hand every day. Germination commenced after about twenty days ; it was successful only where the beds were well shaded by a thick covering of leaves and branches some 18 in. above the ground ; under this shade a large mass of seedlings came up, whereas in beds exposed to the sun hardly any seed germinated. Seedlings can be transplanted without difficulty.

SILVICULTURAL TREATMENT. At present this tree is worked only as a component species of mixed forests, either as coppice-with-standards or under selection and improvement fellings, when, however, it is frequently cut out in the interests of more valuable species such as teak or sal.

As the leaves and bark give promise of furnishing valuable tanning material, it is not unlikely that some system will have to be devised before long for working this species for the production of regular supplies of bark and leaves. The young tender leaves and shoots are richest in tannin. Short rotation coppice, or some modification of it, suggests itself, though the best method remains to be discovered by experiment. Meanwhile the following experiment carried out in Central India is of interest :

A trial coupe of 6 acres on the slopes of the Sharda Devi hill, about 2½ miles from Maihar in Central India, was coppiced in January 1916, about 1,500 trees having been cut to ground-level, leaving rounded stools. The trees were all small and badly shaped. The yield obtained from these was :

Dry leaves	31 maunds (of approximately 82 lb. each).
Dry bark	41 maunds.
Dry fuel	214 maunds.

Within two months of cutting, strong shoots of a bushy growth appeared, covered with fresh leaves rich in tannin. The first flush of leaves was collected and weighed 3 maunds. The method of working proposed in this tract is to continue the collection of the fresh leaves from the coppice-shoots for two or three years and then to leave one strong shoot on each stool to develop into a pole before any further coppicing is carried out. Fresh new leaves are found to be produced on the young coppice-shoots very soon after the shoots have been stripped of leaves.

¹ Ind. Forester, xxxi (1905), p. 637.

The following programme of pollarding and plucking has been adopted tentatively in Central India :

October, November, December : collection of old leaves, only green leaves being suitable.

January, February, March : pollarding and collection of twig bark, once in three years.

April, May, June : collection of sumach (young leaves) once a month ; this is the most important crop.

July, August, September : continued collection of sumach if drying arrangements are possible.

RATE OF GROWTH. The following figures are available of girth measurements in sample plots in high forest :

Anogeissus latifolia : girth increment in high forest sample plots.

Province.	Forest division.	Locality.	No. of years under observation.	No. of trees under observation.	Girth classes, ft.	Mean annual girth increment for period, in.
United Provinces	Lansdowne	Chaukhamb	17	8	1½-3	0.29
		Jogichaur	12	2	1½-3	0.14
		Giwain	4	2	1½-3	0.27
		"	12	10	1½-3	0.63
	Haldwani	Khonani	6	1	1½-3	0.20
	Gonda	Chandanpur	2	13	1½-4	0.16
Central Provinces	Balaghat	Sakra	2	16	1½-3	0.24
		Baihar and Raigarh ranges	8	8	1-2	0.20
Bihar and Orissa	Singhbhum	Tirilposi	25	2	3-4	0.30
				3	4-5	0.32
				1	2-3	0.37
		Samta-Hendakuli	11	4	3-4	0.35
				2	4-5	0.76

Some of these figures probably under-estimate the rate of growth actually attainable, since all these plots are in sal forest, and their main object is to estimate the rate of growth of sal ; hence in thinned plots dominant accessory species would be cut out, and the increment figures would refer to dominated or suppressed trees. Trees raised from seed sown in 1901 by Mr. Haines in the forest garden at Chaibassa, Chota Nagpur, attained the following dimensions in sixteen years :

Height.	Girth.
ft.	ft. in.
35	1 10½
28½	1 10
29	1 6½
28	1 0 (half suppressed)
29	1 3

The annual rings are tolerably clear. Gamble's specimens gave an average of 7 rings per inch of radius, or a mean annual girth increment of 0.9 in. A cross-section in the silvicultural museum at Dehra Dun, measuring 8 ft. 9 in. in girth without bark, had 176 rings, giving a mean annual girth increment of 0.6 in.

Measurements of natural saplings in the Panch Mahals, Bombay, recorded

by Mr. Pearson,¹ give some idea of the rate of growth in youth : the ages were determined by ring-countings on the stumps of felled saplings. The measurements are as follows :

Anogeissus latifolia : rate of growth of natural saplings, Panch Mahals, Bombay.

Age. years.	No. of plants.	Girth. <i>At base.</i>	Height.	Remarks.
4	1	..	7 ft. 4 in.	These measurements are of dominant plants ; very small plants of the same age were also met with.
5	3	3-4 in.	8-10 ft.	
5	3	..	2, 5, and 9 ft.	
		<i>At 4 ft.</i>		
20	5	8, 11, 11, 11½, and 13¼ in.	25, 25, 15, 26, and 20 ft. respectively	

The following table summarizes the available results of measurements in coppice coupes :

Anogeissus latifolia : rate of growth of coppice.

Mean girth and height in different localities.

Age. years.	Saitba block, Kolhan, Bihar and Orissa (1916).		Dehra Dun (A. F. Broun, 1886).		Gorakhpur, U.P. (C. M. McCrie, 1910).		Tikri, Gonda, U.P. (1911).	Bhandara, N. Khandesh, C.P. (1912-13).	N. Khandesh, Bombay (1905).
	girth. in.	height. ft.	girth. in.	height. ft.	girth. in.	height. ft.	height. ft.	height. ft.	height. ft.
1	..	..	..	..	..	..	5	6.2	2.5
2	1.3	4.5	..	..	..	..	..	..	..
4	2.5	8.2	..	..	..	..	..	..	..
6	3.6	10.8	..	..	..	..	..	..	..
8	4.6	13.0	7.5	12.0	..	..	..	..	..
10	5.5	15.0	..	..	..	..	..	..	..
12	6.4	16.8	..	..	..	..	..	..	..
14	7.2	18.0	..	..	..	..	..	..	..
15	..	..	..	..	7.25	22.5	..	..	..

2. *Anogeissus pendula*, Edgew. Vern. *Dhokra*, Ajmer-Merwara ; *Kardhai*, Central India.

A small tree with a short usually crooked bole, readily distinguished from *A. latifolia* by its smaller leaves and graceful slender drooping branches. In exceptional cases the tree reaches a height of 30-40 ft. and a girth of 5 ft., but ordinarily the height is about 20 ft. and the girth 2-3 ft., the stem branching at a height of about 4-5 ft.

The bole yields little or no timber, but poles cut from the branches are in demand for building and other purposes. The leaves contain tannin, and the tree has possibilities as a producer of sumach. In the dry regions in which it occurs this is an important tree, not only as a source of timber and fuel, but also for clothing dry tracts.

DISTRIBUTION AND HABITAT. The tree has a decidedly limited distribution. It extends from the Aravalli hills in Rajputana to Bundelkhand, and from the Kishengarh state and the Jhansi, Hamirpur, and Banda districts of the United Provinces on the north to the Nerbudda in Nimar and the Panch

¹ Ind. Forester, xxxiii (1907), p. 234.



FIG. 207 *Inocassus pendula* SEEDLING.

a. Fruit $\times 1\frac{1}{2}$ b. Germination $\times 1\frac{1}{2}$ c-f. Development of seedling during first season $\times \frac{1}{2}$

Mahals in the south. It is essentially a tree of the dry hot regions ; within its natural habitat the absolute maximum shade temperature varies from 115° to 120° F., the absolute minimum from 30° to 38° F., and the normal rainfall from 17 to 35 in.

The tree is typically gregarious, sometimes forming pure forests and sometimes occurring in mixture with a few other species. In the Aravalli hills of Rajputana, Ajmer and Merwara, which consist of metamorphic and sub-metamorphic rocks—chiefly gneiss, schist, slate, and quartzite with occasional limestone and trap—it often forms almost pure forests of considerable extent, usually occupying the lower and more gentle slopes. The ridges and upper slopes are occupied mainly by *Boswellia serrata*, below which and extending to the foot of the hills *Anogeissus pendula* occurs, particularly if the soil is good. Where the slopes are gentle this tree may extend to the hill-tops ; where the soil is poor it is replaced by *Acacia rupestris*. Besides the two species mentioned, its more important associates in this region are *Acacia Catechu*, *Albizia odoratissima*, *Dalbergia lanceolaria*, *Dichrostachys cinerea*, *Bauhinia racemosa*, and *Grewia* spp., while on the level ground below the *Anogeissus* forests the prevailing species is *Zizyphus Jujuba*.

In the Jhansi district the tree forms practically pure forests on quartzite ridges, other species such as *Diospyros Melanoxylon*, *Acacia Catechu*, *Zizyphus Xylopyrus*, *Bauhinia racemosa*, *Odina Wodier*, and *Butea frondosa* being occasionally scattered with it. The trees here are small and badly shaped, though the forest is often well stocked. Another type of forest in this district is that occurring on undulating to hilly ground on a gneiss formation ; here *Anogeissus pendula* occurs in pure patches or in mixture with *A. latifolia* and *Acacia Catechu*, while the other species previously mentioned occasionally make their appearance.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The leaves, which are green throughout the rainy season, turn a beautiful reddish brown colour in the cold season and commence falling in January, the trees becoming leafless about March and remaining so until about May-June, when the new foliage appears. The small flower-heads, about $\frac{1}{4}$ in. in diameter or less, appear towards the end of the rainy season. The fruits (Fig. 207, a) ripen December-January ; they are small, winged, and nearly orbicular, about 2,700 weighing 1 oz. The tree fruits abundantly nearly every year, but the germinative power of the seed, like that of *A. latifolia*, is usually poor, though tests carried out at Dehra Dun gave a higher percentage of fertility than in the case of *A. latifolia*.

GERMINATION (Fig. 207, b). Epigeous. The radicle emerges from the extremity of the fruit and descends. The hypocotyl elongates, raising the cotyledons above ground. The shell of the fruit encloses the cotyledons at first, and falls with their expansion.

THE SEEDLING (Fig. 207).

Roots : primary root long, thin, terete, wiry : lateral roots moderate in number, short or moderate in length, fibrous, distributed down main root. **Hypocotyl** distinct from root, 0.5-0.6 in. long, terete, minutely tomentose. **Cotyledons :** petiole 0.1 in. long or less : lamina 0.15-0.25 in. by 0.35-0.55 in., foliaceous, reniform, much broader than long, truncate or slightly retuse, base truncate or slightly lobed, entire, green, glabrous. **Stem** erect, terete, wiry, tomentose ; internodes up to 0.5 in. long. **Leaves** simple, first pair usually

opposite or sub-opposite, subsequent leaves alternate, exstipulate. Petiole less than 0.1 in. long. Lamina 0.2–1 in. by 0.1–0.5 in., ovate, acute or acuminate, mucronate, entire, glabrescent above, pubescent on veins beneath, gland-dotted.

SILVICULTURAL CHARACTERS. The tree stands a fair amount of shade in youth, but as saplings appear in quantity in open gaps it seems to require a good deal of light for successful development. It is frost-hardy, but suffers severely from drought in abnormally dry years: in the famine of 1892 in Ajmer the branches of the trees were extensively killed, but new shoots were produced from the stem. The tree coppices and pollards well, but the growth of the coppice-shoots is slow. It produces root-suckers freely.

NATURAL REPRODUCTION. The factors which affect natural reproduction require further study. Reproduction by root-suckers is often plentiful, but seedling reproduction is also frequently good. Like *A. latifolia* the tree tends to regenerate in even-aged masses, and this would indicate that the theory put forward with regard to that species, namely that the production of fertile seed in quantity takes place only after years of scanty rainfall, might apply equally to *A. pendula*. In 1913 seed was sown at Dehra Dun along a ridge of loose earth and also in the trench from which the earth was dug. No seed germinated on the ridge, but several seedlings appeared in the loose alluvial soil accumulated in the trench; none of these, however, survived the rainy season, being killed by an excess of moisture. Definite conclusions cannot be drawn from this solitary experiment, but it might be inferred that, as in the case of *A. latifolia*, shade, or rather protection from a hot sun, is favourable to germination, and also that the seedlings cannot tolerate an excess of moisture.

SILVICULTURAL TREATMENT. Forests of *Anogeissus pendula* are at present treated either under coppice-with-standards or under improvement fellings for the removal of old badly shaped trees over promising young natural crops. A coppice rotation of twenty years in Ajmer has been found to be too short for the production of material of a useful size. In the Jhansi forests Mr. J. Whitehead has suggested that after a provisional period of improvement fellings the most suitable method of treatment, in view of the tendency of this tree to come up in even-aged masses, would be to regenerate in even-aged crops under a shelterwood.¹

RATE OF GROWTH. A cross-section 3 ft. 2 in. in girth, in the silvicultural museum at Dehra Dun, shows 42 rings, representing a mean annual girth increment of 0.9 in., which is fairly fast. This does not accord with observations in the forest, at all events in the case of young plants, whose growth is decidedly slow. Coppice-shoots likewise grow somewhat slowly, particularly in the earlier years. In Ajmer shoots seven years old had a height of 7–8 ft. and a girth of 3–4 in., while shoots eight years old had a height of 10–12 ft. and a girth of 4–7 in.²

3. *Anogeissus acuminata*, Wall. Vern. *Chakwa*, Beng.; *Pasi*, Tel.; *Yôn*, Burm.

A large handsome deciduous tree with a tall straight bole and graceful

¹ Working Plan for the Forests of the Jhansi and Banda Districts, 1911.

² Ajmer-Merwara Working Plan, 1909.

drooping branches. Bark dark grey, in Burma often covered with small globular pustules. The tree is variable. In Burma Kurz distinguishes two varieties: var. 1. *genuina*, with densely pustular bark, frequent in the mixed forests all over Burma; and var. 2. *phillyreaefolia*, with smaller leaves, and bark more or less destitute of pustules, restricted to the savannah and swamp forests of the alluvial plains of Prome and Pegu, and extending to Upper Burma. Haines distinguishes three varieties in Chota Nagpur, of which complete material is wanting.

The wood is moderately hard, but is inferior to that of *A. latifolia*; it is not durable, and warps and cracks in seasoning.

DISTRIBUTION AND HABITAT. The tree is found in limited quantity in Chota Nagpur (Singhbhum district), extending southward through Orissa, the Northern Circars, and the Chanda district, Central Provinces. It is found typically along the banks of streams on alluvial ground. It occurs in the Chittagong hill tracts, and is a common forest tree throughout the greater part of Burma, extending to the borders of the dry zone. In Burma it is frequent not only along river banks, but also in the upper mixed deciduous forests with teak and its associates. It is, however, perhaps most plentiful in the lower mixed deciduous forests of the plains, along with *Dillenia pentagyna*, *Terminalia tomentosa*, *T. belerica*, *T. Chebula*, *Schleichera trijuga*, *Odina Wodier*, *Dalbergia cultrata*, *Vitex glabrata*, *Eugenia Jambolana*, *Adina cordifolia*, *Stephegyne diversifolia*, and in the better drained localities teak, *Xylia dolabriformis*, and *Homalium tomentosum*. It extends into low-lying swampy ground, and is one of the most characteristic species of the freshwater swamp forests of the plains, which are inundated during the rainy season. It is, however, not confined to moist localities, but is common in certain dry regions, for example in the Ruby Mines district, where it occurs in open dry forest on somewhat poor shallow soil, the trees being of small size; here it is associated with *Terminalia tomentosa*, *Acacia Catechu*, *Diospyros burmanica*, *Vitex pubescens*, *Pterocarpus macrocarpus*, and others.

In its natural habitat the absolute maximum shade temperature varies from 100° to 115° F., the absolute minimum from 40° to 55° F., and the normal rainfall from 35 to 120 in. or more.

LEAF-SHEDDING, FLOWERING, AND FRUITING. In Burma the tree is leafless for a short time in the hot season; the flowers appear in February–March, and the fruits ripen in April–May, falling as soon as they ripen. In Chota Nagpur, according to Haines, the flowers appear in March–April and the fruits commence ripening in April. About 1,100 to 1,800 of the fruits weigh 1 oz. The seed, like that of other species of this genus, is very unfertile. No fewer than fifteen tests under different conditions were carried out at Dehra Dun in two separate years with samples of seed from three different localities in Burma, and in no case did a single seed germinate.

NATURAL REPRODUCTION. Notwithstanding the unfertile nature of the seed, natural reproduction of this tree in Burma is often very good, young plants sometimes forming dense even-aged thickets, particularly on alluvial ground in places where the fruits have been washed into heaps along with silt. In the case of *A. latifolia* it has been suggested that fertile seed is produced only in certain years, probably following on seasons of deficient rainfall.

Although it is possible that in the case of *A. acuminata* the production of quantities of fertile seed may take place only in certain years, the reason for this cannot be any deficiency of rainfall, since this does not occur throughout the greater part of its habitat in Burma.

3. LUMNITZERA, Willd.

Lumnitzera racemosa, Willd. Vern. *Kirpa*, Beng. ; *Yinyè*, Burm.

An evergreen shrub or small tree of the mangrove swamps along the coasts of India and Burma, an account of which is given on pp. 496-500. It extends also into the tidal forests behind the mangrove swamps, occurring chiefly on the banks of streams. The wood is hard and durable, and is used for house-posts and for fuel. Flowers March-April ; fruits September (Talbot). Its root-system is superficial, the roots bending out of the mud in the form of knees for breathing purposes.

ORDER XXVIII. MYRTACEAE

An important order containing some useful Indian trees (*Eugenia*, *Careya*) and a number of introduced species, mainly of the great Australasian genus *Eucalyptus*, several of which have become thoroughly acclimatized in India. Among trees and shrubs yielding edible fruits may be mentioned *Psidium Guayava*, Linn., the guava, introduced from tropical America and grown all over India, *Eugenia Jambos*, *E. Jambolana*, and other species of *Eugenia*, and *Rhodomyrtus tomentosa*, Wight, the hill gooseberry of the Nilgiris. Many of the species have aromatic and coriaceous leaves, and exhibit xerophytic characters, as seen for example in the pendulous leaves of *Eucalyptus*. Their silvicultural requirements vary considerably even in different species of the same genus. Of those which thrive in moist and even swampy ground may be mentioned *Barringtonia* and several species of *Eucalyptus* and *Eugenia*, while other members of the last two genera are found on dry poor ground. Of hardy fire-resisting species characteristic of burnt savannah lands, the most important are *Careya arborea* and *Eugenia operculata*. Many of the members of this order coppice with great vigour.

Genera 1. *EUGENIA*, Linn. ; 2. *EUCALYPTUS*, L'Hérit. ; 3. *BARRINGTONIA*, Forst. ; 4. *CAREYA*, Roxb. ; 5. *PLANCHONIA*, Bl.

1. *EUGENIA*, Linn.

This genus is probably richer in tree species than any other Indian genus. Brandis (*Indian Trees*) enumerates no fewer than 79 species, chiefly trees, with a few shrubs ; of these 76 or 77 are indigenous. They are nearly always evergreen, with gland-dotted often coriaceous leaves, which with rare exceptions are opposite. The fruit is a one- or few-seeded berry, often succulent, sometimes nearly dry. The great majority of the species are moisture-loving, and are found in moist localities, often in evergreen forest, while several grow along the banks and in the beds of streams. *E. formosa*, Wall., a large-leaved species with ternate leaves up to 18 in. long, often grows in the beds of perennial



FIG. 208. *Eugenia Jambolana* on bank of stream. United Provinces



FIG. 209 *Euphoria Jambolana* growing gregariously along bank of stream and worked as coppice,
Gosalthur district United Provinces

streams with its roots permanently in water. *E. Heyneana*, Wall., a willow-like shrubby species, grows in the beds of streams, and is often inundated for a considerable period during the rainy season. *E. Jambolana*, Lam., and others, sometimes grow under similar conditions. Some species, on the other hand, grow in dry types of forest and exhibit xerophytic tendencies. Thus *E. Jambolana* itself is the most characteristic tree of the dwarf evergreen formation on the laterite of the Mahableshwar plateau, Bombay, while the variety *caryophyllaefolia*, Lam., of the same species, is found on dry hills in Chota Nagpur. *E. grandis*, Wight, occurs on dry ridges in Upper Burma.

Several species of this genus are rare or local, and on the whole the trees are, with one or two exceptions, not of great importance in Indian forestry. By far the most important generally is *E. Jambolana*, Lam. In the sal forests of northern India, *E. operculata*, Roxb., is a useful species from a silvicultural point of view.

Species 1. *E. Jambolana*, Lam.; 2. *E. operculata*, Roxb.; 3. *E. Jambos*, Linn.

1. **Eugenia Jambolana**, Lam. Black plum. Vern. *Jáman*, Hind.; *Jambul*, Mar.; *Nerlu*, Kan.; *Naval*, Tam.; *Neredu*, Tel.; *Thabyè*, Burm. (Fig. 208.)

A large evergreen tree with a dense shady much-branched crown of shining dark green foliage and usually a rather crooked bole. Bark up to 1 in. thick, light to dark grey or brown, fairly smooth, with shallow depressions caused by exfoliation, red inside. Wood moderately hard, fairly durable, used for common building, agricultural implements, well curbs, and other purposes; an excellent fuel. This is an important forest tree, and is also largely planted on roadsides and in gardens for shade or ornament and for the sake of its edible fruits. It is variable as regards the shape of the leaves and the size and shape of the flowers and the fruits.

Sometimes it reaches a very large girth: Mr. J. C. McDonnell¹ records one 20 ft. 6 in. in girth by the Saruinsar lake, Jammu.

DISTRIBUTION AND HABITAT. Common throughout India and Burma, except in the most arid regions. Also in the Andamans, Ceylon, the Malay Archipelago, and southward to Australia. In the Himalayan valleys it ascends to 4,000 ft. or sometimes more, and in the Nilgiris to 6,000 ft. It is found in a variety of situations, but most typically along streams and in damp and even marshy localities, where it is often gregarious (see Figs. 209, 211). In the Indian Peninsula a variety with narrow leaves is very common on alluvial sand or loam in the beds and along the banks of watercourses which are often dry for several months in the year. The tree is, however, by no means confined to very moist situations. It is a common constituent of the sal forests. It is the commonest species of the stunted evergreen forest on the laterite of the Mahableshwar plateau in the Bombay Presidency, forming roughly 50 per cent. of the stock and associated with *Actinodaphne Hookeri*, *Mamecylon edule*, *Flacourtia Ramontchi*, *Terminalia Chebula*, *Olea dioica*, and *Canthium didymum*. The plateau is exposed, the ground often rocky, and the soil shallow, while the rainfall is heavy (over 200 in.), most of the rain falling in July and August; the trees seldom grow more than 25 ft. high, and have short thick boles and low flat crowns.

¹ Ind. Forester, xxix (1903), p. 152.

The narrow-leaved variety, *caryophyllaefolia*, Lam., is mentioned by Haines¹ as being very common in dry open forest on the hills of Singhbhum, Palamau, and Manbhum; this variety, as noted below, exhibits the xerophytic character of dying back in the seedling stage.

In Burma the tree occurs in various types of mixed deciduous forest, both upper and lower, in tropical evergreen forest, and in *indaing* (dry dipterocarp) forest on laterite, here again occurring in a xerophytic environment. In Travancore it is common on the Peermerd plateau at 4,000 ft., and elsewhere in the evergreen forests of the hills (Bourdillon).

In its natural habitat in India and Burma the absolute maximum shade temperature varies from 95° to 118° F., the absolute minimum from 28° to 65° F., and the normal rainfall from 35 to over 200 in.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The leaves usually commence falling about January and continue falling during February and March. The new leaves, which are coppery red in colour, appear in February–March. In dry localities the trees become almost, if not quite, leafless for a short time early in the hot season. Sometimes trees with large quantities of blossom become almost leafless.

The panicles of small greenish white sweet-scented flowers appear chiefly from March to May. The fruit (Fig. 210, *a*), which ripens from June to August, is an oblong-obovoid or sub-globose juicy berry, 0.5–1 in. long, or larger under cultivation, purplish-black, smooth and shining when ripe, with a thin skin and a pink succulent flesh, which is edible though somewhat astringent. The seed (Fig. 210, *b*) is 0.4–0.8 in. long, shaped like the fruit, or two to five angular and irregularly shaped seeds are compressed together into a mass resembling a single seed, the whole enclosed in a sub-coriaceous covering.

The germinative power of fresh seed is high, but the seed very quickly loses its vitality. The fruits fall as soon as they ripen; they are eagerly devoured by birds and flying foxes, and the seed is spread by their agency.

GERMINATION (Fig. 210, *c, d*). Hypogeous. The covering enclosing the seeds quickly rots off, leaving the green interior (cotyledons), which usually breaks up into two or more portions, from each of which a seedling is produced; usually two or three, sometimes four or even five, seedlings emerge from one fruit; the cotyledons remain in or on the ground.

THE SEEDLING (Fig. 210).

Roots: primary root moderately long and thick, terete, tapering, wiry; lateral roots numerous, moderately long, fibrous, distributed down main root or often crowded at its base. **Hypocotyl** very short and scarcely distinguishable, subterranean. **Cotyledons** irregular in shape and size, angular, fleshly, green, subterranean. **Stem** erect, quadrangular, green or pinkish, glabrous; internodes 0.2–1.2 in. long. **Leaves** simple, exstipulate, first few often abortive, 0.1–0.2 in. long, sometimes alternate or sub-opposite, subsequent normal leaves opposite. **Petiole** 0.1 in. long or less, channelled above. **Lamina** 0.7–2 in. by 0.4–1 in., ovate, obovate or elliptical, apex acute or sometimes obtuse, base acute, entire, glabrous, coriaceous, aromatic when crushed.

The development of the seedling is slow during the first season, but under favourable conditions is more rapid during the second and subsequent years.

¹ For. Flora Chota Nagpur, p. 351.



FIG. 210. *Eugenia Jambolana*—SEEDLING. $\times \frac{1}{2}$

a—Fruits b—Seed c - d—Germination stages e - h Development of seedling during first season
i—Seedling early in second season

In the case of the normal moisture-loving variety seedlings are very sensitive to drought if exposed to the sun, mortality commencing as early as September or October, and being particularly common during the subsequent hot season. Even under shade, seedlings have been observed to die off on dry ground. Soil moisture, indeed, appears to be of more importance than shade, since seedlings develop well even if exposed to the sun, provided the soil is kept moist. Under natural conditions, however, or where watering is not carried out, shade is of great benefit in preventing the desiccation of the soil and the death of the seedlings.

A striking instance of the value of shade occurred in connexion with experimental line sowings at Dehra Dun. Two lines of *Eugenia Jambolana*, 1½ ft. apart, were sown early in the rains along a clear strip 3 ft. wide, with the object of ascertaining the value of this species as a nurse to sal, a line of which was sown between the two lines of *Eugenia*. The strip ran from north-west to south-east, and on either side of it field crops (lesser millet) were sown; these field crops grew rapidly and attained a height of 3½ ft. by the end of the rains. The direction of the strip was such that one line of *Eugenia* received shade from the sun from midday onwards, while the other line was exposed to the sun. The seed germinated along both lines, and the seedlings developed well during the rainy season. On the sunny line, however, high mortality from drought occurred in September–October, and continued to some extent subsequently, the result being that whereas the shady line continued to be well stocked with vigorous seedlings, very few plants survived until the following rains in the parallel line exposed to the sun. Fig. 212 shows the appearance of the two lines a year after sowing.

In the case of var. *caryophyllaeifolia*, Lam., I have noticed numerous seedlings in Singhbhum in open hill forest, growing on the driest ground in situations exposed to the sun; these seedlings, like those of many other species in dry localities, were observed to have died back annually for some years in their early stages, new shoots having been sent up each year from the base or from lateral buds. This great dissimilarity in the habit of this form from that of the normal seedling lends colour to Haines's suggestion as to this form being a separate species.

The seedling is capable of struggling well amongst weeds, but its development suffers. Weeding and watering, particularly the former, have a marked effect on its growth and vigour. On stiff soil the development is poor. Where, as is frequently the case, the seedlings are in dense masses, the more vigorous individuals rapidly suppress the more weakly plants. The seedlings are somewhat frost-tender, particularly on grassy ground, where they are frequently killed back. The season's growth continues until November–December, new growth commencing in February or March (northern India). The taproot reaches only a moderate length during the first season, showing greater development during the second year, when it attains a length up to 2 ft. or more.

The following measurements, made in experimental plots at Dehra Dun, give some indication of the dimensions attained by young plants under different conditions :

Eugenia Jambolana : development of seedlings, Dehra Dun.

Condition under which grown.	Height and other particulars at end of season.		
	1st season.	2nd season.	3rd season.
(1) Nursery plants watered and weeded	Maximum 0 ft. 4½ in.		
(2) Irrigated sowings, full sun-light, weeded	Maximum 0 ft. 6½ in.	0 ft. 4 in.-4 ft. 1 in.	Maximum 8 ft. 0 in. (dense mass of strong thick-stemmed plants)
(3) Irrigated sowings, full sun-light, unweeded	Maximum 0 ft. 6 in.	0 ft. 3 in.-1 ft. 3 in.	0 ft. 8 in.-3 ft. 1 in. (condition somewhat poor)
(4) Unirrigated sowings, full sun-light, weeded	Maximum 0 ft. 10½ in.	0 ft. 7 in.-3 ft. 8 in. (vigorous, the larger suppressing the smaller)	
(5) Unirrigated sowings, full sun-light, unweeded	Maximum 0 ft. 6 in.	0 ft. 6½ in.-0 ft. 10 in.	
(6) Unirrigated sowings, in partial shade, weeded	Maximum 0 ft. 4½ in.	Maximum 2 ft. 3 in.	
(7) Unirrigated sowings, in partial shade, weeded	Maximum 0 ft. 5 in.	Maximum 2 ft. 0 in.	
(8) Transplants in partial shade	Maximum 0 ft. 3 in.	Maximum 1 ft. 6 in.	0 ft. 11 in.-2 ft. 7 in.

Nos. 2 to 5 demonstrate the great value of weeding. Fig. 213 shows Nos. 2 and 3 during the second season; the effect of weeding, as shown on the left of the staff, is very marked in comparison with the unweeded plot on the right of it.

SILVICULTURAL CHARACTERS. *Eugenia Jambolana* is a shade-bearer, particularly in youth; dense masses of young plants may be found coming up under moderate shade near streams and in other moist places, while seedlings and saplings are often found under shade in sal forest and other types of forest. Although somewhat frost-tender in youth, it is hardier later, and in the abnormal frost of 1905 in northern India it was not much affected. In the abnormal drought of 1907 and 1908 in Oudh it proved to be hardy in the sal forests, but along streams and in swamps it suffered when the water dried up. It is not readily browsed by cattle.

The tree possesses remarkable coppicing power, shoots being produced in large quantities, chiefly round the periphery of the cut surface of the stool: large stumps as well as small ones produce shoots as a rule. Figs. 209, 211, and 215 show the appearance of pure coppice on rich alluvial land, subject to inundation in the rainy season, along the banks of streams in the Gorakhpur district, United Provinces. At an age of four years, with a height of 15 ft., there are often more than thirty shoots on one stump, more than half of them being usually dominant. The soil requirements of the tree have already been alluded to; they are somewhat contradictory, though the differences appear in some cases to coincide with well-marked botanical varieties.

NATURAL REPRODUCTION. The fruits fall in quantity under and around the parent trees early in the rainy season; the seeds are washed into heaps by the rain, germination quickly taking place on moist ground and in pools of mud. Each fruit may produce from one to four or even five seedlings clustered together, and the seedlings often appear in dense masses: this is particularly the case on alluvial ground, where as many as 100 seedlings about 6 in. high to the square foot have been counted after the end of the rainy

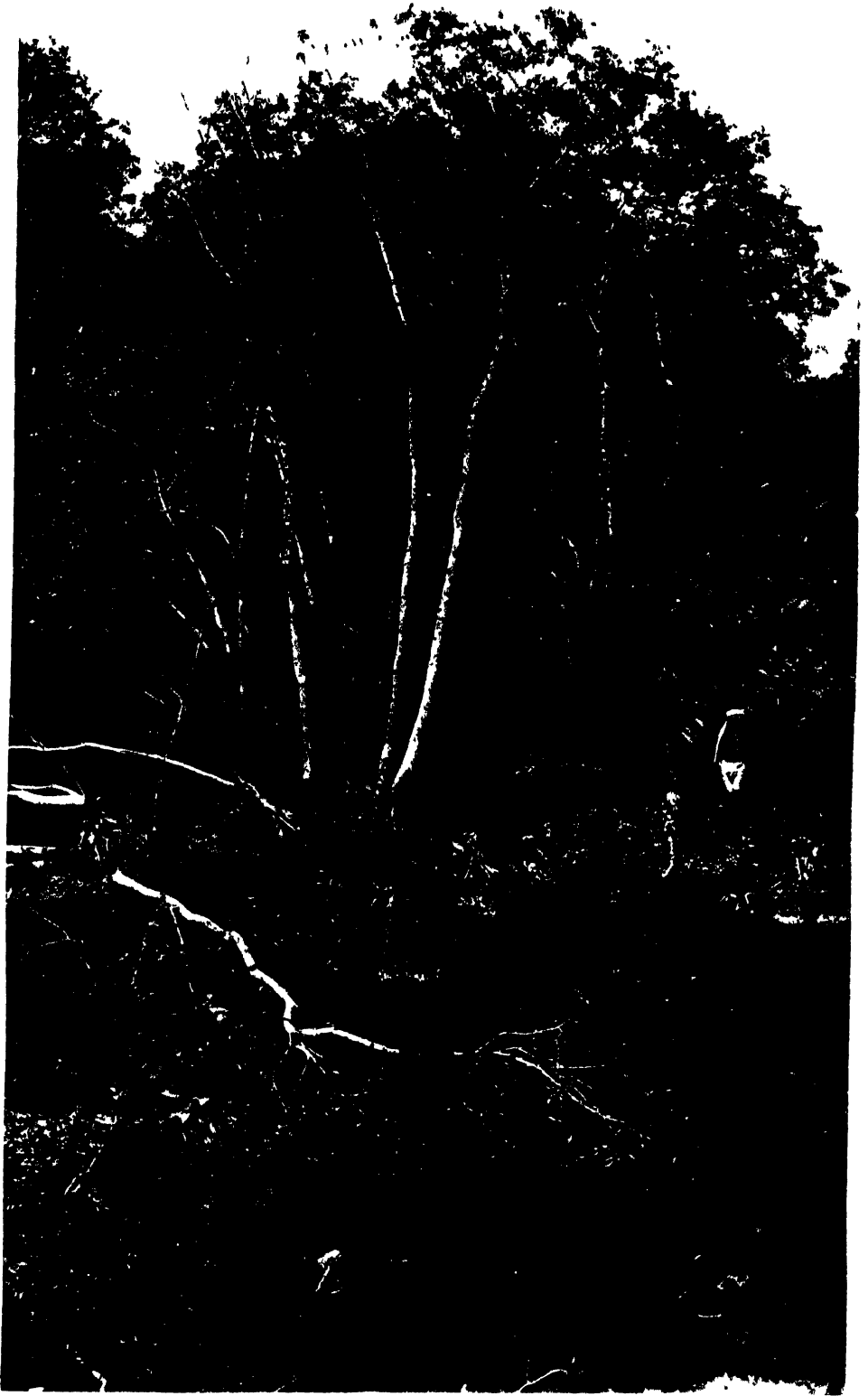


FIG. 211. *Eugenia Jambolanx* coppice 30 ft. high in process of being felled on swampy ground, Gorakhpur district, United Provinces.



A

B

FIG 212 *Eugenia Jambolana*, line sowings in second year, showing beneficial effect of side shade, Dehra Dun Lane on left (A) exposed to the sun for a considerable part of the day, with the result that nearly all the plants have died of drought : line on right (B) receives side shade for most of the day, with the result that there has been little or no mortality from drought.

season on sandy alluvium. Fig. 214 shows profuse growth of seedlings at the end of the first season. Sometimes two or three tiers of seedlings of different years may be found under the same seed-bearer, showing to what an extent the young plants will stand shade. Seedlings often occur sporadically in the forest where there are no seed-bearers in the neighbourhood, the seed having been disseminated by the agency of birds. The necessity for soil moisture in the establishment of natural reproduction and the mortality which takes place on dry ground, even under shade, have already been noted under 'the seedling'; indeed, the value of shade appears to lie mainly in its power of preventing desiccation of the soil.

The exceptional case in which natural seedlings of var. *caryophyllaefolia* establish themselves on dry hilly ground after dying back for some years in succession has already been alluded to: possibly this may also be found to be the case with seedlings growing on laterite.

ARTIFICIAL REPRODUCTION. So far as experiments show, direct sowing is preferable to transplanting, since there is usually a considerable proportion of failure during transplanting, in spite of precautions. Of the forms of direct sowing tried so far, line sowings kept regularly weeded have proved the most successful, but it is essential that the soil should be kept moist, and where irrigation cannot be carried out, shade is necessary. This can be effected by means of narrow cleared and well-hoed lines under the shade of an overwood or cut through low growth, so as to retain shade and at the same time allow of regular weeding: side shade is of more importance than overhead shade. The seed should be sown early in the rainy season, as soon as it ripens.

Sowings of *Eugenia Jambolana* to fill open grassy or other blanks have been repeatedly tried, but they have almost invariably resulted in failure except along the edge of the surrounding forest, where side shade is obtained from the sun.

For transplanting purposes the greatest success is obtained by sowing in baskets, two or three seeds in each, and retaining the healthiest seedling in each basket. The baskets are kept well watered under moderate shade, and are planted out during the second rains. For forest purposes transplanting should usually be done under shade unless the ground is permanently moist. Roadside trees usually require watering in dry weather for the first year or two. Transplanting from nursery beds requires care, as the seedlings do not stand much exposure of or injury to the roots. Natural seedlings in the forest can be transplanted successfully in moist places or under shade.

SILVICULTURAL TREATMENT. In the forest the tree is ordinarily treated as an accessory species and worked along with other species in coppice coupes or in selection fellings. In private forests on alluvial ground along river-banks in parts of Oudh, pure crops of this species are worked very successfully as simple coppice for the production of poles (see Figs. 211 and 215). The rotation is usually a short one, about 10–15 years, or sometimes less, and judging by the density of the crops the yield must be high: these areas are grazed, but the cattle do not appear to damage the coppice-shoots to any extent.

RATE OF GROWTH. (1) *High forest.* The following statement gives a summary of available girth measurements in high forest sample plots:

Eugenia Jambolana : girth increment in high forest sample plots.

Province.	Forest division.	Locality.	No. of years under measurement.	No. of trees under measurement.	Girth classes.	Mean annual girth increment for period.
					ft.	in.
United Provinces	Dehra Dun	Sherpur forest	4	1	0-1	0.41
	Lansdowne	Chaukhamb	17	2	1½-3	0.70
		Giwain	4	1	1½-3	0.13
		Barswar	4	14	1½-4	0.33
		Jogichaur	4	1	6-8	0.32
	Ramnagar	Mandal	1	3	1½-3	0.40
		S. Patli Dun	19	5	0-3	0.27
		Domanda	19	1	1½-3	0.36
	Haldwani	Silani	11	4	1½-6	0.61
	S. Kheri	Kishanpur	9	1	4-5	0.09
	Gonda	Chandanpur	2	1	0-1½	0.15
		Sakra	2	2	1½-3	0.30
Central Provinces	Balaghat	Raigarh and Baihar ranges }	8	{ 2	1-2	0.47
				{ 2	2-3	0.31

The sample plots in question are situated in sal forest, and the rate of growth shown is probably slower than what might be expected on moist alluvial ground near streams.

Ring-countings made in 1905 by Mr. D. A. Thomson in respect of nine trees in the Supa fuel reserves, North Kanara, Bombay, gave the following results : ¹

Eugenia Jambolana : rate of growth in Supa fuel reserves, North Kanara.

Age in years	5	10	15	20	25	30	35	40	45	50	55
Mean diameter (inches) . .	1.06	2.16	3.26	4.38	5.48	6.58	7.60	8.78	9.82	10.73	11.13
Corresponding girth (inches)	3.2	6.6	10.1	13.5	17.2	20.7	23.9	27.6	31.4	33.8	35.0

A cross-section from the United Provinces in the silvicultural museum at Dehra Dun, measuring 3 ft. 3 in. in girth, had 34 rings, representing a mean annual girth increment of 1.15 in. Measurements in 1907 of eight planted trees, sixteen years old, in the Thapal grant estate, Saharanpur, United Provinces, gave an average girth of 2 ft. 4 in. and an average height of 25.7 ft., which shows that under favourable conditions the growth is fairly fast.

2. *Coppice*. On fertile ground coppice-shoots grow rapidly. On rich alluvium along river banks in Gorakhpur, Oudh, coppice four years old showed an average height of 15 ft. In Nellore, Madras, a height of 6 ft. was attained by coppice-shoots in eight months.² Measurements made in 1911 in the Tikri forest, Gonda, United Provinces, showed for an age of two years an average height of 7 ft., as against 7.6 ft. for sal.

The following measurements made in 1886 by Mr. A. F. Broun in the Bullawala sal coppice, Dehra Dun, compare the rate of growth of *Eugenia Jambolana* coppice with that of sal :

Growth of *Eugenia Jambolana* and sal coppice, Bullawala, Dehra Dun.

Age. years.	Mean girth.		Mean height.	
	<i>Eugenia</i> . in.	Sal. in.	<i>Eugenia</i> . ft. in.	Sal. ft. in.
8	7.5	8.3	16 4	16 2.5
8	6.5	7.1	14 6	13 1.9
9	7.2	8.7	10 0	13 5.5
10	9.0	5.9	14 0	11 10.6

¹ Working Plan for the Supa Fuel Reserves, 1907.

² Forest Report, 1909-10.



FIG. 213. *Eugenia Jambolana* plants 13 months old from broadcast sowings, showing beneficial effect of weeding, Dehra Dun: on left of staff, plot regularly weeded contains 88 vigorous seedlings up to 3 ft. 9 in. in height; on right of staff, plot sown at same time and left unweeded contains 23 seedlings up to 1 ft. 3 in. in height struggling through grass and weeds



FIG. 214. *Eugenia Jambolana*, natural reproduction on soft sandy soil, end of first season, seedlings about 6 m. high, Tirsal forest, Dehra Dun, United Provinces. Note dense mass of seedlings in upper part of picture.

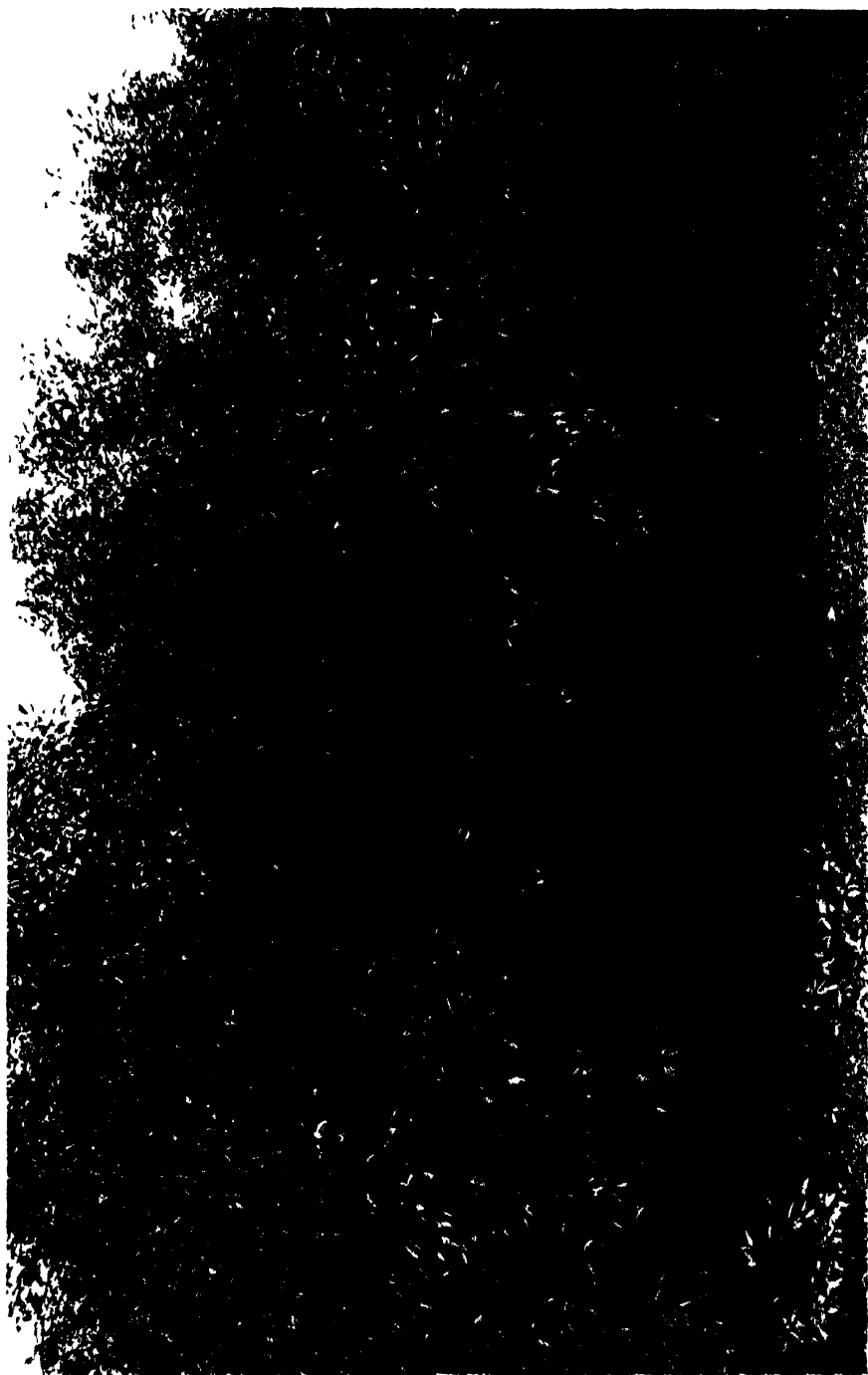


FIG. 215 *Eugenia Jambolana* coppice, 4 years old, 15 ft. high, on alluvial ground along the bank of a stream. Gorakhpur district, United Provinces.

Measurements made in 1910 by Mr. C. M. McCrie in sal coppice in Gorakhpur, United Provinces, showed the following growth for *Eugenia* and sal respectively :

Growth of *Eugenia Jambolana* and sal coppice, Gorakhpur.

Age. years.	Mean girth.		Mean height.	
	<i>Eugenia.</i> in.	Sal. in.	<i>Eugenia.</i> ft. in.	Sal. ft. in.
2	—	—	2 0	3 0
4	2·0	2·0	4 8	7 0
6	3·0	2·9	7 0	10 4
8	3·8	3·8	8 5	13 0
10	4·5	4·8	10 0	15 4

2. *Eugenia operculata*, Roxb. Vern. *Piáman*, *Rai jáman*, Hind. ; *Kón thabyè*, Burm.

A moderate-sized evergreen tree with a short bole and spreading branches. Leaves coriaceous, turning red in the cold season. Found in the sub-Himalayan tract, Bihar, Orissa, Assam, Chittagong, and Burma. This is a familiar tree in the sal forests of northern India, particularly on grassy savannahs and blanks, where it is often the first tree to appear, and being fire-resisting and frost-hardy, it establishes itself in such localities and forms a useful nurse to sal, which regenerates well under its protection. In their earlier stages, however, the seedlings are sensitive to frost. In northern India the fruits ripen about August. The growth is slow to moderate. Sample plot measurements in sal forest in the United Provinces give the following results :

Eugenia operculata : girth increment in sample plots, United Provinces.

Forest division.	Locality.	No. of years under measurement.	No. of trees under measurement.	Girth classes. ft.	Mean annual girth increment for period. in.
Lansdowne	Barswar	4	5	1½-3	0·34
Ramnagar	S. Patli Dun	19	2	0-3	0·17

A cross-section 6 ft. 3 in. in girth, in the silvicultural museum at Dehra Dun, has 83 rings, giving a mean annual girth increment of 0·9 in.

The tree coppices well, and the coppice-shoots sometimes show fairly rapid growth. Measurements of coppice made in 1911 in the Tikri forest, Gonda, United Provinces, showed an average height of 6 ft. in two years, compared with 7 ft. 7 in. for sal ; the average number of shoots per stool was two as compared with 1·8 for sal. Measurements by Mr. C. M. McCrie in 1910 in a coppice coupe three years old in Gorakhpur, United Provinces, showed an average height of 7 ft. 6 in. as against 9 ft. 7 in. for sal. Measurements in 1886 by Mr. A. F. Broun in the Bullawala coppice coupes, Dehra Dun, showed the following growth of *Eugenia operculata* as compared with sal :

Eugenia operculata : growth in coppice coupes, Bullawala, Dehra Dun.

Age. years.	Mean girth.		Mean height.	
	<i>Eugenia operculata.</i> in.	Sal. in.	<i>Eugenia operculata.</i> ft. in.	Sal. ft. in.
8	8·1	8·3	17 4·4	16 2·5
8	6·2	7·1	13 6·6	13 1·9
9	15·2	8·7	17 5·5	13 5·5
10	10·5	5·9	18 3·6	11 10·6

These coupes are subject to occasional severe frosts which damage the sal coppice, and this accounts for the poor growth of the sal in some cases.

3. *Eugenia Jambos*, Linn. Rose apple. Vern. *Guláb jáman*, Hind.

A tree cultivated in many parts of India and Burma for its fruit, which is rather insipid though sweet-scented. According to Brandis it is indigenous in the Malay Archipelago and in Upper Burma (Shwebo district, at 1,000 ft. on stream banks). It has run wild in many places. The handsome flowers, with large yellowish white bunches of stamens, usually appear from February to April. The fruits ripen from June to August, and drop at once; the seeds germinate soon after falling, and large quantities of seedlings may be found under and around the trees during the rainy season, as in the case of *E. Jambolana*. These survive if the locality is sufficiently moist and shady, but if exposed to the sun they die off rapidly. This habit coincides exactly with that of the common form of *E. Jambolana*, and it is possible that on closer study of the various species it may be found to be fairly general in the case of those which grow in moist localities.

2. EUCALYPTUS, L'Héritier.

An Australasian genus consisting of about 140 species, most of which are found in Australia and some in Tasmania, New Guinea, and other islands. The eucalypts are evergreen trees, all more or less aromatic and containing oil-glands in the leaves; the oil distilled from the leaves of some species is of value in medicine. The leaves of young trees, of young coppice-shoots, and of shoots sent out after injury by fire or otherwise, are generally opposite, sessile, and horizontal, and are often of a different shape from the normal leaves of the adult tree; the latter are usually alternate, petiolate, and hang vertically. The flowers are white or red, and the flower-buds have the calyx-tube covered with a lid or operculum which falls off when the flowers open. The fruit is a woody capsule, consisting of the hard calyx-tube and containing numerous small seeds, a considerable proportion of which are usually unfertile.

The eucalypts contain several of the most important timber trees of the Australian continent, where they form large tracts of forest, some growing pure and others mixed. Some of them reach gigantic size, and are among the largest trees in the world, specimens of the blue gum (*E. Globulus*, Labill.) and peppermint gum (*E. regnans*, F. v. M., formerly included under *E. amygdalina*, Labill.) having been stated to reach a height of over 400 ft.

INTRODUCTION INTO FOREIGN COUNTRIES. The eucalypts appear first to have attracted attention outside their natural home in the early part of the nineteenth century, when seed began to be introduced into southern Europe, and the trees, probably for the most part *E. Globulus*, began to be cultivated, first for ornament or as curiosities, and later, when their rapid growth and economic importance began to be realized, in plantations. Since then eucalypts have been extensively planted in the Mediterranean region, in California, Florida, Hawaii, and several other parts of the western hemisphere, in South Africa, and in other sub-tropical and warm temperate regions throughout the globe.

INTRODUCTION INTO AND CULTIVATION IN INDIA. The introduction of

eucalypts into India probably dates from 1843, when a few trees were planted experimentally in the Nilgiris mainly with the object of finding some species capable of yielding regular and plentiful supplies of fuel: regular plantations, chiefly of *E. Globulus*, were commenced in these hills in 1856, and have been extended subsequently on a large scale. Numerous species have since been tried under all sorts of climatic and other conditions in many parts of India and Burma, both in the hills and on the plains. Some details of the results attained in different localities are given below, but it may be said generally that some species or other of eucalyptus has been found which is suited to almost any climate in India with the possible exception of: (1) very moist tropical regions, where the seedlings damp off in spite of all precautions; and (2) elevations above the winter snow-line, where snow-break is to be feared. It is, however, possible that species may yet be found which will grow well in localities where eucalypts have failed hitherto, for although several species have been proved to thrive well in India under given conditions, the introduction of a large number is as yet in the initial stage of experiment or has not yet been attempted.

The extension of eucalyptus cultivation in India has its advocates and its opponents. The former urge the great utility of these trees in supplying fast-growing timber and fuel as well as oil, tannin, and other products, their swamp-draining capacity and their direct anti-malarial value, though from a medical point of view the last-named quality appears to be problematical. The latter maintain that the extension of eucalyptus cultivation in India has gone far enough, that the trees are monotonous, and that in regions where they are capable of growing it is possible to grow indigenous trees which furnish better timber and are superior in every way except so far as rapidity of growth is concerned. There is something to be said on both sides. It is true that as timber trees the eucalypts have not come up to expectations in India, but that is no reason for believing that some good timber species may not yet be found which will be capable of profitable cultivation. On the other hand, so far as fuel production goes, the rapidity of growth and the volume-production of the eucalypts in places where they do thrive far exceed anything attainable by indigenous species. The blue gum has conferred an inestimable boon on the Nilgiris, and those who complain of the monotony of the eucalypts which dominate the landscape on the Nilgiri plateau should remember that these trees saved a fuel famine in the middle of last century, while in Ootacamund and the adjoining stations they now yield plentiful supplies of fuel, obtainable at far cheaper rates than is the case in any other hill station in India. Where large supplies of quick-growing and therefore cheap fuel are required, there seems to be every reason for the extension of eucalyptus plantations in India in places where these trees will grow well and furnish higher yields than indigenous species; while, again, the experimental introduction of little-known or new species, which has been proceeding for several years past, is all to the good, since it tends towards a solution of the question of cheap supplies of fuel and possibly of timber. Provided, therefore, the extension of eucalyptus cultivation in India is confined to cases where it is likely to be of distinct advantage, and does not involve the clearing of valuable indigenous timber species, there is much to be said in favour of it.

Much experimental work has been carried out in the past, and continues to be carried out, in the cultivation of eucalyptus in India, but in spite of this the records of results are in most cases disappointing, and are often unreliable. Fruitful sources of error are the wrong naming of seeds, the inadvertent mixing of seeds of different species, the interchanging of labels of plants in different stages, as well as errors and omissions in maintaining the records. Again, it frequently happens that a species grows well for a few years and then fails; it is favourably reported on for some years and the record then ceases, though the plant has by this time acquired an undeserved reputation, and is wrongly recorded as a success. It is therefore of little use judging of the suitability of a species for a given locality until it has reached reasonable dimensions and shown its adaptability to its new environment. Mistakes in identification are very common, and have been the cause of a good deal of confusion in the past. For the correct identification of the eucalypts, botanical specimens should be as complete as possible, and should ordinarily include primordial as well as adult leaves, flowers, fruits, and bark: as these are not all obtainable at the same time, great care is necessary to ensure that the specimens are all collected from the same tree.

Numerous failures in the past have been due to the fact that trees from the temperate regions of Australasia have been repeatedly tried in the hotter parts of India, while those from the tropical and other warm regions of that continent have been tried at cool elevations in the hills. Generally speaking it may be laid down that for low elevations in India, if any species is to have a reasonable chance of succeeding it must be obtained from the tropical and warm parts of Queensland and adjacent northern regions, where also are found such well-known Indian trees as *Bombax malabaricum*, *Eugenia Jambolana*, *Barringtonia racemosa*, *Alstonia scholaris*, *Mallotus philippinensis*, *Trema orientalis*, *Ficus glomerata*, and *Casuarina equisetifolia*. On the other hand, species from Tasmania and the southern parts of Australia only are likely to be successful at the higher elevations in India. To quote one example: the blue gum (*E. Globulus*), a tree of Tasmania and the south-eastern parts of Australia, has been tried time and again at low elevations in India, but has always failed signally, whereas at the higher elevations in the Nilgiris it has been a remarkable success.

The results attained hitherto in different parts of India, so far as records are available, are of some interest, and may prove to be useful as a guide towards the selection of species for further experiment.

1. *The Nilgiris.* The introduction of eucalypts in 1843, and the formation of plantations from 1856 onwards, have already been alluded to. In 1914 the total area of Government eucalyptus plantations, either pure or mixed with acacia, amounted to 1,089 acres, in addition to which there are numerous privately owned plantations. Fuel from these is supplied at extremely cheap rates. The altitude of the plantations varies from 5,000 to 8,300 ft. The principal rock is a fine-grained gneiss decomposing into a red clay: there is a marked absence of lime in the soil.

The climate of the Nilgiris is cool, equable, and moist, with a well-distributed rainfall of about 50 to 80 in. The winter is on the whole mild, with only occasional frosts of more than slight intensity, and these are of short

duration ; snow is unknown. The following climatological statistics may be quoted :

Climatological statistics for the Nilgiris.

Station.	Shade temperature (degrees Fahr.).				Normal rainfall (inches).				
	Maximum.		Minimum.		Jan.- Mar.	Apr.- May.	June-Sept. (SW. monsoon).	Oct.-Dec. (NE. monsoon).	Total for year.
	Absolute.	Average.	Absolute.	Average.					
Ootacamund (7,327 ft.)	..	75	..	35	2.46	9.70	24.76	14.03	50.95
Coonoor (6,200 ft.)	..	..	..	..	8.17	8.82	16.68	32.09	65.76
Wellington (6,200 ft.)	83.4	81	24.7	36	..	..	..	..	51.09

The species far more extensively planted than any other is *E. Globulus*, which grows very rapidly and thrives admirably. Many other species, however, have been planted, not only in plantations but also in private gardens and along roadsides, while there are many different species in the Government gardens at Ootacamund and in Sim's Park at Coonoor. The identity of many of these was obscure until, in 1912 and subsequently, Mr. R. Bourne made a careful investigation into the question, and with the aid of specimens collected on the spot succeeded in establishing the identity of no fewer than 36 species. After *E. Globulus* by far the commonest species in the Government plantations are *E. obliqua* and *E. Sieberiana*. Except *E. Globulus* the only two species which have attained large dimensions are *E. obliqua* and *E. eugenoides*, to which may be added occasional large specimens of *E. viminalis*. The following is a complete list of species which Mr. Bourne has succeeded in identifying in the Nilgiris: *E. acmenoides*, Schauer, *E. amygdalina*, Labill., *E. botryoides*, Sm., *E. calophylla*, Brown, *E. capitellata*, Sm., *E. cornuta*, Labill., *E. corymbosa*, Sm., *E. crebra*, F. v. M., *E. eugenoides*, Sieber, *E. ficifolia*, F. v. M., *E. foecunda*, Schauer, *E. Globulus*, Labill., *E. Gunnii*, Hook., *E. hemiphloia*, F. v. M., *E. Leucoxydon*, F. v. M., *E. longifolia*, Link and Otto, *E. macrorrhyncha*, F. v. M., *E. maculata*, Hook., var. *citriodora*, Bailey, *E. microcorys*, F. v. M., *E. miniata*, Cunn., *E. obliqua*, L'Hérit., *E. paniculata*, Sm., *E. ptychocarpa*, F. v. M., *E. pilularis*, Sm., *E. pulverulenta*, Sims., *E. punctata*, DC., *E. redunca*, Schauer, *E. resinifera*, Sm., *E. robusta*, Sm., *E. rostrata*, Schleich, *E. saligna*, Sm., *E. siderophloia*, Benth., *E. Sieberiana*, F. v. M., *E. Stuartiana*, F. v. M., *E. tereticornis*, Sm., *E. viminalis*, Labill.

Trials were commenced in 1910 to ascertain if any good timber-yielding species will succeed in the Nilgiris, and for this purpose small experimental plantations were formed at three different elevations, namely 6,700, 7,300, and 8,300 ft. The species tried were *E. acmenoides*, Schauer, *E. crebra*, F. v. M., *E. eugenoides*, Sieber, *E. hemiphloia*, F. v. M., *E. paniculata*, Sm., *E. pilularis*, Sm., *E. punctata*, DC., and *E. siderophloia*, Benth. There was some difficulty in raising the young plants, which proved tender in the early stages, and had to be reared under forcing frames. When once put out they proved more hardy, but required protection against frost, for which purpose they were surrounded with coverings of bracken. The species which have done best so far are *E. punctata*, *E. acmenoides*, and *E. pilularis*. The least promising is *E. hemiphloia*.

2. *Indian Peninsula.* Except in the Nilgiris there is little reliable informa-

tion regarding the results of planting eucalypts in the Indian Peninsula. Probably the most successful species so far tried at low elevations is *E. tereticornis*, which grows well even at Bombay; *E. rostrata* also does well at low elevations, and is grown at Poona and elsewhere. Attempts made about 1874-6 at Saugor in the Central Provinces, to grow certain species, including *E. cornuta*, *E. Globulus*, *E. marginata*, *E. obliqua*, *E. rostrata*, *E. Sideroxylon*, and *E. viminalis*, resulted in failure. *E. Globulus* was tried in 1909 in coast sand in the Madras Presidency, but needless to say the result was a failure. In the same year *E. marginata*, *E. resinifera*, and *E. rostrata* were sown in the Sanyasimalai plantation in North Salem at an elevation of 4,000 ft.; the seedlings thrived the first year, but no subsequent information is available. Eleven different species were tried at Mercara in Coorg in 1913; those which proved the most successful during the first few years were *E. maculata*, *E. pilularis*, *E. punctata*, *E. goniocalyx*, *E. saligna*, and *E. resinifera*. Plants of *E. maculata* three years old had a maximum height of 21 ft. and a maximum girth of 7 in.

3. *Himalaya*. Eucalypts have been grown in various parts of the Himalaya for many years, but at elevations where there is any appreciable snowfall in winter they have suffered so severely from snow-break that they are now recognized to be unsuitable for planting except at the lower elevations. *E. Globulus* is probably the species which has been planted most extensively, and it has grown well except for liability to snow-break; *E. Sideroxylon* is reported to have done well in the Kumaun hills. Mr. R. N. Parker notes that at Abbottabad (elevation 4,000 ft.), where eucalypts are extensively grown, the species seen are *E. tereticornis*, *E. rostrata*, *E. Sideroxylon*, *E. maculata* var. *citriodora*, and *E. Globulus*.¹ Prior to the abnormal frost of 1905 *E. Globulus* was far commoner than it is now, but all the trees were badly injured and many were killed outright in that year. At present *E. tereticornis* is by far the commonest species in that station: there are also several specimens of *E. Sideroxylon*, and one each of *E. rostrata* and *E. maculata* var. *citriodora*, dating from before 1905.

Experiments in the cultivation of eucalyptus in the Simla hills have been in progress for some years past, the most complete of these dating from 1909, when small experimental plots were established at various elevations along the Kalka-Simla railway and in the neighbourhood of Simla itself. The cultivation was carried out by means of direct sowings on roughly prepared ground, no watering being done. So far the following have been found to succeed, to some extent at least, at different elevations:

(a) Under 4,000 ft.: *E. calophylla*, R. Br.*, *E. cornuta*, Labill., *E. corynocalyx*, F. v. M., *E. eximia*, Schauer*, *E. gomphocephala*, DC., *E. goniocalyx*, F. v. M., *E. Gunnii*, Hook., *E. hemiphloia*, F. v. M., *E. Leucoxylon*, F. v. M.*, *E. longifolia*, Link and Otto*, *E. Maidenii*, F. v. M., *E. melliodora*, A. Cunn., *E. microcorys*, F. v. M., *E. paniculata*, Sm.*, *E. punctata*, DC., *E. resinifera*, Sm., *E. rostrata*, Schlecht*, *E. rudis*, Endl., *E. Stuartiana*, F. v. M., *E. tereticornis*, Sm.*

(b) 4,000-6,000 ft.: *E. amygdalina*, Labill., *E. Cambagei*, Deane and Maiden*, *E. coriacea*, A. Cunn., *E. corynocalyx*, F. v. M., *E. crebra*, F. v. M.,

¹ Ind. Forester, xxxix (1913), p. 81.

E. eugenioides, Sieb., *E. eximia*, Schauer*, *E. Globulus*, Labill.*, *E. gomphcephala*, DC., *E. Gunnii*, Hook.*, *E. hemiphloia*, F. v. M., *E. longifolia*, Link and Otto*, *E. Maidenii*, F. v. M.*, *E. melliodora*, A. Cunn., *E. Planchoniana*, F. v. M., *E. regnans*, F. v. M., *E. rudis*, Endl., *E. saligna*, Sm., *E. Sideroxylon*, A. Cunn., *E. Stuartiana*, F. v. M.*, *E. tereticornis*, Sm., *E. viminalis*, Labill.*

(c) 6,000–7,000 ft. : *E. Cambagei*, Deane and Maiden, *E. corymbosa*, Sm., *E. corynocalyx*, F. v. M., *E. crebra*, F. v. M., *E. Globulus*, Labill., *E. Gunnii*, Hook.*, *E. hemiphloia*, F. v. M., *E. Maidenii*, F. v. M.*, *E. Stuartiana*, F. v. M.*, *E. viminalis*, Labill.*

(d) Over 7,000 ft. : *E. corymbosa*, Sm., *E. corynocalyx*, F. v. M., *E. crebra*, F. v. M., *E. melliodora*, A. Cunn., *E. saligna*, Sm.

Those marked with an asterisk have so far proved the most successful. Above 5,000 ft. the results have not been nearly so satisfactory as they have below that elevation, though this is ascribed more to poverty of soil than to elevation. Species which have so far proved unsuitable for introduction on a large scale are *E. haemastoma*, Sm., *E. macrorrhyncha*, F. v. M., *E. Muelleriana*, Howett, *E. obliqua*, L'Hérit., *E. pauciflora*, Sieb., *E. pilularis*, Sm., *E. piperita*, Sm., *E. Sieberiana*, F. v. M.

Further experiments are in progress in the Simla hills with numerous other species, and these may be expected to yield definite results in due course.

4. *Sub-Himalayan tract and plains of northern India.* Eucalypts were first introduced into northern India about 1860, and numerous species have been tried. The reports of the Government gardens at Lucknow, Lahore, and Saharanpur contain the results of various trials from time to time. In the Changa Manga irrigated plantation near Lahore various species were introduced many years ago, while more recently experiments on a considerable scale have been carried out there and in the Kot Lakhpat plantation.

Mr. R. N. Parker¹ enumerates the following species found growing on the Punjab plains, which he has been able to identify with tolerable certainty, though he admits that the list is by no means complete :

E. maculata, Hook., var. *citriodora*, Bailey. Less common than the following two in the Punjab, but the commonest species in Saharanpur and Dehra Dun.

E. tereticornis, Sm. This and the next are the commonest species in the Punjab, and have given the best results where extensive trials have been made. Almost the only species in the Rawalpindi and Hazara districts. Succeeds well in the Hoshiarpur district. Not common at Saharanpur and Dehra Dun.

E. rostrata, Schl. Very common on the Punjab plains ; seldom seen in Rawalpindi and Hazara. Does well at Saharanpur.

E. crebra, F. v. M. Occasionally seen in Lahore, Amritsar, Kapurthala, Changa Manga, and Saharanpur.

E. melanophloia, F. v. M. Grown in Lahore, Changa Manga, Agra, and Saharanpur.

E. saligna, Sm. Grows well at Amritsar and Saharanpur.

E. robusta, Sm. Occasionally grown in Lahore, Kapurthala, Saharanpur, and Agra.

¹ *loc. cit.*

E. siderophloia, Benth. One specimen in Changa Manga doing well.

E. Sideroxylon, A. Cunn. Several in Changa Manga, not doing very well.

The first three of the above species are by far the commonest grown in the plains and sub-Himalayan tract.

According to Mr. Parker the following species have been sufficiently tried to show that they are quite unsuitable for planting on the plains :

E. amygdalina, Labill., *E. capitellata*, Sm., *E. coccifera*, Hook. f., *E. coriacea*, A. Cunn. (*E. pauciflora*, Sieb.), *E. corymbosa*, Sm., *E. Globulus*, Labill., *E. goniocalyx*, F. v. M., *E. Gunnii*, Hook. f., *E. haemastoma*, Sm., *E. macrorrhynca*, F. v. M., *E. marginata*, Sm., *E. obliqua*, L'Hérit., *E. pilularis*, Sm., *E. piperita*, Sm., *E. resinifera*, Sm., *E. Sieberiana*, F. v. M., *E. Stuartiana*, F. v. M., *E. urnigera*, Hook. f., *E. viminalis*, Labill., *E. virgata*, Sieb. (*E. stricta*, Sieb.).

The following species appear to be unlikely to thrive on the plains, though evidence is not yet conclusive :

E. acmenoides, Schau., *E. alpina*, Lindl., *E. Andrewsii*, Maiden, *E. Baileyana*, F. v. M., *E. calophylla*, R. Br., *E. cinerea*, F. v. M., *E. corynocalyx*, F. v. M., *E. delegatensis*, R. T. Baker, *E. dives*, Schau., *E. eugenoides*, Sieb., *E. eximia*, Schau., *E. ficifolia*, F. v. M., *E. longifolia*, Link and Otto, *E. Luehmanniana*, F. v. M., *E. Macarthuri*, Deane and Maiden., *E. macrandra*, F. v. M., *E. macrocarpa*, Hook., *E. Muelleriana*, Howett, *E. occidentalis*, Endl., *E. obcordata*, Turcz. (*E. Platypus*, Hook.), *E. Planchoniana*, F. v. M., *E. regnans*, F. v. M., *E. rubida*, Deane and Maiden, *E. Smithii*, R. T. Baker, *E. stellulata*, Sieb., *E. trachyphloia*, F. v. M., *E. umbra*, R. T. Baker.

Many other species are under trial. At Lahore, among species which have shown promise during the first few years are *E. gomphocephala*, DC., *E. hemiphloia*, F. v. M., *E. melanophloia*, F. v. M., *E. melliodora*, A. Cunn., and *E. rudis*, Endl. The last named has shown extraordinary growth on poor saline soil, and appears to be well suited for such ground. *E. Kirtoniana*, F. v. M., does well if it gets sufficient water. At Saharanpur the most successful so far, apart from those already mentioned, are *E. microcorys*, F. v. M., *E. obliqua*, L'Hérit., *E. paniculata*, Sm., and *E. rudis*, Endl. The following, recently grown at Dehra Dun, are well established : *E. bicolor*, A. Cunn., *E. botryoides*, Sm., *E. microcorys*, F. v. M., *E. patentinervis*, R. T. Baker, *E. rostrata*, Schl., *E. saligna*, Sm., *E. Sideroxylon*, A. Cunn. ; of these *E. bicolor*, *E. botryoides*, and *E. Sideroxylon* are regarded as failures at Saharanpur.

The following climatological statistics for plains and low-level stations in northern India give some indication of the conditions under which the above-mentioned species have been tried :

Climatological statistics for some plains and low-level stations in northern India.

Station.	Shade temperature (prior to 1903).		Normal rainfall. in.	
	Absolute maximum. degrees F.	Absolute minimum. degrees F.		
Lahore	120.3	29.2	20	The great bulk of the rain falls during the SW. monsoon from July to September ; the remainder of the year is dry except for occasional showers or bursts of rain.
Saharanpur	116	30	38	
Lucknow	119	30	38	
Agra	120	30	26	
Dehra Dun	111	33.9	85	

5. *Assam*. *E. Globulus* thrives at Shillong, showing rapid growth and attaining very fair dimensions.

6. *Burma*. Eucalypts have been tried from time to time in various parts of Burma. At Maymyo (elevation 3,500 ft.) planting was commenced about the year 1893; the species which has proved most successful there is *E. rostrata*, though *E. amygdalina* and *E. maculata* var. *citriodora* have also done well, and *E. resinifera* fairly well. These species are likely to do well on the Shan States plateau should plantations be required there. There is a fine avenue in the Maymyo bazaar consisting chiefly of *E. rostrata*. *E. Globulus* has proved a failure at Maymyo, but has succeeded in the hills of the Ruby Mines district. The species which has done best at low elevations is *E. viminalis*, which has proved hardy. *E. cornuta* was reported in 1911-12 to be growing well in a rubber plantation at Kwanhla in the Amherst township.

7. *Andamans*: Seventeen species were tried in the Andamans in 1914, but after the first year the only species showing any promise were *E. resinifera*, *E. robusta*, *E. rostrata*, and *E. tereticornis*. Two species, namely *E. botryoides* and *E. robusta*, were tried in mangrove swamps, but were unable to stand the salt water.

SILVICULTURAL CHARACTERS. Eucalypts, as a rule, are intolerant of shade, though many species tend to branch low if grown in isolated positions, and in early youth seedlings endure a little shade for a time. Many species coppice well, but the blue gum (*E. Globulus*) is probably the most vigorous of all the better known species in this respect. The root-system is usually of a spreading type, the roots penetrating for a considerable distance in search of moisture; superficial spreading roots are common. Eucalypts are generally speaking wind-firm, but many species are liable to become bent, gnarled, and stunted in exposed situations. Species tried at the higher elevations in the Himalaya have been found very liable to snow-break. Fire does little damage to older trees with thick persistent bark, but young trees and those with thin or deciduous bark suffer severely: those whose bark exfoliates in long dry strips, like *E. Globulus*, suffer much damage, the fire ascending up the loose bark into the crowns. Most species have good power of recovery from damage by fire. Injured trees produce shoots with primordial leaves, and a blue gum plantation which has recently been burnt presents a silvery-blue appearance, owing to the production of these shoots. The most aromatic eucalypts are not readily browsed by cattle; two species particularly susceptible to this form of damage are *E. corynocalyx*, whose leaves have a sweetish taste, and *E. Gunnii*, whose leaves are not strongly aromatic. Plantations of young trees near Dehra Dun have suffered much through rubbing by deer, the aromatic bark attracting these animals; where deer are prevalent, fencing may therefore be necessary. In the Changa Manga plantation in the Lahore district, seedlings are browsed down by *nilgai* in the winter, and when the plants are out of reach of browsing these animals gnaw the bark.

The requirements of the various species as regards soil and climate vary considerably. Some details are given under the individual species described below, but so far as Indian conditions go our knowledge is confined to a comparatively small number of species which have been tried in different localities. Much experimental work remains to be done in discovering species suitable

for the diverse climates and types of soil met with in India, for experience has shown that it is most unsafe to predict the behaviour of a newly tried species in India, even though its requirements are well understood in its natural home. Generally speaking, most if not all eucalypts grow best on deep fresh soil with a fair amount of subsoil moisture; many, however, accommodate themselves to poor dry soils, swampy ground, exposed situations, high altitudes, or other conditions unfavourable to their best development, and here they often assume a stunted or misshapen form or display special characteristics amounting to sub-specific variation, for example in the form of the bark, the shape and size of the leaves, or the amount of essential oil contained in them.

The following are some examples of species whose requirements are tolerably well known :

Suitable for wet ground : *E. rostrata* (probably the best for swampy ground), *E. robusta*, and to some extent *E. botryoides*, *E. Globulus*, and *E. tereticornis*.

Suitable for dry, poor soil : *E. corynocalyx*, *E. resinifera*, *E. siderophloia*, *E. Sieberiana*.

Exacting as to soil : *E. Globulus*, *E. pilularis*.

Not exacting as to soil (i. e. will tolerate dry as well as unduly moist soils) : *E. amygdalina*, *E. cornuta*, *E. resinifera*, *E. robusta*, *E. rudis*, *E. Sideroxylon*, *E. viminalis*.

Suitable for saline soils : *E. rudis*.

Frost-resistant : *E. coriacea*, *E. Gunnii*, *E. resinifera*, *E. rostrata*, *E. siderophloia*, *E. tereticornis*, *E. viminalis*.

Frost-tender : *E. calophylla*, *E. maculata* var. *citriodora*.

The following list of relative frost-hardiness of different species of *Eucalyptus* has been drawn up by Mr. E. N. Munns as a result of observations during an exceptional period of low temperature in South California : ¹

Very resistant to low temperatures : *E. viminalis*, *E. polyanthema*, *E. Gunnii*, *E. regnans*, *E. crebra*.

Resistant to low temperatures : *E. tereticornis*, *E. rostrata*, *E. Globulus*, *E. coriacea*, *E. resinifera*, *E. corynocalyx*, *E. robusta*, *E. goniocalyx*.

Frost-sensitive, but capable of recovering from injury : *E. Sideroxylon*, *E. Stuartiana*, *E. citriodora*, *E. longifolia*, *E. amygdalina*, *E. saligna*.

Very frost-sensitive : *E. rudis*, *E. corymbosa*, *E. Leucoxylon*, *E. cornuta*, *E. diversicolor*, *E. calophylla*.

Drought-resistant : *E. corynocalyx*, *E. resinifera*.

Drought-tender : *E. Globulus*, *E. maculata* var. *citriodora*, *E. obliqua*, *E. saligna*.

NATURAL REPRODUCTION. So far as India is concerned, the question of natural reproduction from seed is at present of no consequence. To a limited extent natural seedlings have been springing up in and around the blue gum plantations of the Nilgiris for some years past, and the essential conditions appear to be bare soil free of weeds and sufficient light. In Australia it is generally recognized that natural reproduction can be secured without much difficulty by cutting the undergrowth, passing fire over the area, and thereafter strictly protecting from fire and in the first few years from grazing ; these methods usually result in a good crop of natural seedlings, from seed

¹ Journal of Forestry, xvi (April 1918), p. 412.

lying dormant or falling subsequent to the fire, wherever there is sufficient light for their development.

ARTIFICIAL REPRODUCTION. The artificial raising of eucalypts requires a considerable amount of care: the seeds are small and are easily washed away by rain, while the young seedlings of many species are sensitive to drought or frost and for some little time after germination are very liable to damp off with excessive moisture.

Direct sowings are less commonly employed than transplanting, but *E. crebra* was sown with success at Dehra Dun on alluvial ground in lines with the aid of field crops, a cleared strip 3 ft. wide in which the eucalypts were sown being left unsown with the field crop; two lines of eucalypts $1\frac{1}{2}$ ft. apart were sown, with a line of sal between them, the object of the former being to act as a protection to the sal against frost and drought. The field crop employed was the lesser millet or *mandwa* (*Eleusine coracana*), which was sown in June and reaped in October, and the eucalyptus was sown in August, $1\frac{1}{2}$ oz. of seed being used for sowing the double line 74 ft. long. The eucalypt seedlings died off in quantity in the first dry season, but a sufficient number survived to produce thickly stocked lines, the dominant plants reaching a height of 5–6 ft. in eighteen months; they were then much in need of thinning out, and their subsequent development was poor owing to their congested state. This experiment is not conclusive, but this method of sowing is worth further trial where seed is plentiful. Experimental broadcast sowings have been carried out since 1909 in small patches in the Simla hills, and the results have been noted on pp. 560 and 561; more recently sowings on a larger scale have been tried, but the results have not proved successful.

Nursery treatment. The methods of raising eucalypt seedlings in the nursery vary considerably, and local experience alone can decide which method to adopt in any particular case. Experience has shown that the best time for sowing the seed in most parts of India, both in the hills and on the plains, is early spring, about February–March or even as early as January in the hills; this enables the seedlings to reach a size large enough for planting out at the beginning of the rainy season. The cheapest method of raising seedlings is to rear them in seed-beds, which should be well raised and should consist of a mixture of fine leaf-mould and sand. The surface having been well smoothed and moderately, not excessively, watered, the seed is sown broadcast on the surface and lightly covered with a layer of fine earth. The seed-beds should be kept moist with a fine spray until germination begins: from the commencement the beds should be protected by a covering, raised about 12 in. above them, of thatch or other material impervious enough to prevent rain from dripping through, these screens being removed in dull cloudy weather and replaced to protect the beds and seedlings from sun, frost, or heavy rain. The seedlings require a fair amount of water, but excess of moisture causes damping off. The beds should never be flooded; watering should be done frequently but sparingly with a fine spray.

Flat boxes about 4 or 5 in. deep are in many ways preferable to seed-beds, and for new species as yet untried or of which only a limited quantity of seed is available they should certainly be adopted. The bottoms of the boxes should have a number of small holes bored in them for drainage purposes,

and otherwise the same precautions as regards soil, watering, and protection should be employed. An open shed is useful for protecting the boxes of seedlings during heavy rain and frosty weather or in the heat of the day. One special advantage of seed-boxes is that they can be protected against ants, which carry off the seeds, and white ants, which destroy the roots of young seedlings: the boxes may be isolated by placing them on stones wrapped in cloth soaked with kerosene oil or on stands the legs of which rest in tins of water. In place of boxes, kerosene tins cut in half, with holes punctured on the under side, may be employed.

Whether raised in seed-beds or in boxes, the seedlings on attaining a height of 2 to 4 in. should be pricked out 2 to 3 in. apart, either in nursery-beds or in boxes, and shaded for the first two or three days. Pricking out requires much care, as the seedlings are sensitive to any damage to stem or roots. On attaining a height of about 6 in. they may require pricking out again, or what is preferable, they may be planted individually in baskets or pots made of stiff paper about 8 or 9 in. deep, or in bamboo tubes open at either end, the lower end being stopped up with grass or other material; in transplanting the baskets or pots are buried bodily, the bottoms having been broken open, while in the case of the bamboo tubes the plant is forced down through the tube into the planting hole, the tube being removed. In this way there is no disturbance of the roots during transplanting. Clay pots at least 7 in. deep may also be employed, the seedlings being carefully removed from them, with the earth intact, for planting purposes. In the Nilgiris the system of mossing is sometimes adopted, the roots of the seedling, enclosed in a ball of earth, being wrapped round with moss with the object of retaining moisture; the mossed plants are placed on the ground under partial shade, regularly watered, and shifted slightly every few days to prevent the roots from fixing themselves in the ground.

Where baskets, pots, &c., are employed, the preliminary pricking out is sometimes dispensed with, the seedlings being transferred to them straight from the seed-beds or boxes. For planting out purposes where seedlings have been pricked out in boxes the boxes of seedlings should, if possible, be conveyed to the planting site and the seedlings should be removed from the boxes by means of a trowel, with as little disturbance of the earth round the roots as possible. If transplanting is to be carried out in a dry situation the plants should be gradually hardened in the nursery by giving them more and more sun and less and less water.

Planting and spacing. In India the best time for planting is about the beginning of the rainy season, and for forest purposes seedlings about 12 in. in height are the most suitable. Winter planting has been tried in the Himalaya, but the results were less successful than in the case of monsoon planting. It is advantageous to dig the pits two or three months beforehand and expose the soil; in low-lying or swampy ground it may be found advisable to plant on slightly raised mounds.

The question of spacing is somewhat debatable, and probably the only definite conclusions arrived at so far in India are in respect of the blue gum plantations in the Nilgiris, where in the earlier years various spacings from 6 ft. by 6 ft. to 9 ft. by 9 ft. were adopted. At first opinions varied as to

the results likely to be attained, but there is now no doubt whatever that a spacing of 9 ft. by 9 ft. is preferable to one of 6 ft. by 6 ft., and that there is no occasion to plant closer than 8 ft. by 8 ft.; these wider spacings not only give equally good, if not better results, but also reduce the cost of formation considerably. As regards other species and conditions, accurate information is wanting as to the best spacings to adopt in India. Generally speaking, however, wide spacings, say 8 ft. by 8 ft. to 10 ft. by 10 ft., are indicated on good soils, and for species which grow vigorously and tend to form clean boles, while closer spacings are necessary on poor soils and for species which develop more slowly and tend to branch low. It is doubtful if a spacing of less than 6 ft. by 6 ft. is ever indicated in India if a plantation is to prove profitable.

Subsequent tending. For the first year, or sometimes two years, it may be necessary to protect the young plants from frost by means of cowls of grass or bracken. Hand watering is not ordinarily practicable under forest conditions on a large scale; most eucalypts, however, respond to irrigation. Thinnings first become necessary as a rule from the sixth to the tenth year, and the effect of regular thinnings on the yield and on the subsequent development of the crop is most marked.

SYSTEM OF WORKING. So far as India is concerned, the Nilgiri blue gum plantations are the only ones which have as yet been worked regularly, the system adopted being for the most part simple coppice for the production of fuel: hitherto the rotation adopted has been ten years, but this has recently been increased to fifteen years. A few of the less accessible plantations have been left as high forest to be felled later, and as far as can be foreseen the best method of regeneration will be by clear-felling and replanting. Coppice-with-standards has been tried in the Nilgiris, but the results were unsatisfactory owing to the poor growth of the coppice, and this system has been abandoned in the Government plantations. Some further details regarding the working of the Nilgiri plantations will be found below under *E. Globulus*.

PARTICULARS REGARDING SPECIES. Information regarding most of the species which have hitherto been tried in India is given below. Particulars as to the characters and occurrence of these trees in their natural home have been taken mainly from von Mueller's *Eucalyptographia*, Maiden's *Critical Revision of the Genus Eucalyptus* and *Flora of New South Wales*, Baker and Smith's *Research on the Eucalypts*, Bentham's *Flora Australiensis*, and Bailey's *Queensland Woods*.

Species (in alphabetical order) 1. *E. acmenoides*, Schauer; 2. *E. alpina*, Lindl.; 3. *E. amygdalina*, Labill.; 4. *E. Andrewsi*, Maiden; 5. *E. Baileyana*, F. v. M.; 6. *E. bicolor*, A. Cunn.; 7. *E. botryoides*, Smith; 8. *E. calophylla*, R. Br.; 9. *E. Cambagei*, Deane and Maiden; 10. *E. capitellata*, Smith; 11. *E. cinerea*, F. v. M.; [*E. citriodora*, Hook., see 36. *E. maculata*, Hook.; *E. coccifera*, Hook. f., see 3. *E. amygdalina*, Labill.]; 12. *E. coriacea*, A. Cunn.; 13. *E. cornuta*, Labill.; 14. *E. corymbosa*, Smith; 15. *E. corynocalyx*, F. v. M.; 16. *E. crebra*, F. v. M.; 17. *E. delegatensis*, R. T. Baker; 18. *E. dives*, Schauer; 19. *E. eugenoides*, Sieber; 20. *E. eximia*, Schauer; 21. *E. ficifolia*, F. v. M.; 22. *E. foecunda*, Schauer; 23. *E. Globulus*, Labill.; 24. *E. gomphocephala*, DC.; 25. *E. goniocalyx*, F. v. M.; 26. *E. Gunnii*, Hook.; 27. *E.*

haemastoma, Smith; 28. *E. hemiphloia*, F. v. M.; 29. *E. Kirtoniana*, F. v. M.; 30. *E. Leucoxylon*, F. v. M.; 31. *E. longifolia*, Link and Otto; 32. *E. macrandra*, F. v. M.; 33. *E. Macarthuri*, Deane and Maiden; 34. *E. macrocarpa*, Hook.; 35. *E. macrorrhyncha*, F. v. M.; 36. *E. maculata*, Hook.; 37. *E. Maideni*, F. v. M.; 38. *E. marginata*, Smith; 39. *E. melanophloia*, F. v. M.; 40. *E. melliodora*, A. Cunn.; 41. *E. microcorys*, F. v. M.; 42. *E. miniata*, Cunn.; 43. *E. Muelleriana*, Howett; 44. *E. obcordata*, Turcz.; 45. *E. obliqua*, L'Hérit.; [*E. obtusifolia*, DC., see 74. *E. virgata*, Sieb.]; 46. *E. occidentalis*, Endlicher; 47. *E. paniculata*, Smith; 48. *E. patentinervis*, R. T. Baker; [*E. pauciflora*, Sieb., see 12. *E. coriacea*, A. Cunn.]; 49. *E. pilularis*, Smith; 50. *E. piperita*, Smith; 51. *E. Planchoniana*, F. v. M.; [*E. Platypus*, Hook., see 44. *E. obcordata*, Turcz.]; 52. *E. ptychocarpa*, F. v. M.; 53. *E. pulverulenta*, Sims.; 54. *E. punctata*, DC.; 55. *E. redunca*, Schauer; 56. *E. regnans*, F. v. M.; 57. *E. resinifera*, Smith; 58. *E. robusta*, Smith; 59. *E. rostrata*, Schlecht; 60. *E. rubida*, Deane and Maiden; 61. *E. rudis*, Endl.; 62. *E. saligna*, Smith; 63. *E. siderophloia*, Benth.; 64. *E. Sideroxylon*, A. Cunn.; 65. *E. Sieberiana*, F. v. M.; 66. *E. Smithii*, R. T. Baker; 67. *E. stellulata*, Sieb.; [*E. stricta*, Sieb., see 74. *E. virgata*, Sieb.]; 68. *E. Stuartiana*, F. v. M.; 69. *E. tereticornis*, Smith; 70. *E. trachyphloia*, F. v. M.; 71. *E. umbra*, R. T. Baker; 72. *E. urnigera*, Hook. f.; 73. *E. viminalis*, Labill.; 74. *E. virgata*, Sieb.

1. *Eucalyptus acmenoides*, Schauer. White mahogany.

A fairly tall straight-growing tree with drooping rather bushy foliage. Bark persistent, fibrous. Wood strong, tough and durable, used for posts, piles, building, &c.; posts are said to have lasted over fifty years in Australia. Indigenous in eastern New South Wales and Queensland, growing well on well-drained sterile hills. There are a few specimens in the Nilgiris. Mr. R. Bourne gives the following: (1) Coonoor Peak; (2) below Cluny Hall; (3) St. Thomas's churchyard. It is being experimented with further as a plantation tree and has done well so far. It has not attained a large size in the Nilgiris. It is being tried on the plains of northern India, but appears unlikely to thrive.

2. *Eucalyptus alpina*, Lindl.

A shrubby rare alpine species found on Mount William, Victoria, at an elevation of over 4,000 ft. Very slow-growing and of dwarf habit. Has recently been tried on the plains of northern India, but is most unlikely to succeed. A curiosity and not a species of commercial importance.

3. *Eucalyptus amygdalina*, Labill., including *E. regnans*, F. v. M. Giant gum, peppermint gum.

Maiden separates the two species, but they are here considered together because it is not yet certain to which belong the trees grown under the name of *E. amygdalina* in India. In its native home *E. regnans* is the largest of the eucalypts, trees over 400 ft. high having been recorded (F. v. Mueller). The stem is tall, straight and clean, with smooth almost white bark, and the foliage feathery and handsome. New South Wales, Victoria (eastern humid districts), and Tasmania, up to 4,000 ft. It attains its largest dimensions in well-watered ravines of the cooler ranges; in open country and on ridges it is a much smaller tree. Wood fairly light, floating in water, unlike that of most eucalypts, not very durable underground, but used for shingles, planking, and palings.

The leaves are very rich in oil, but perhaps this refers to the variety known as the peppermint gum, with fragrant leaves. The tree is grown to a certain extent in the Nilgiris: Mr. R. Bourne mentions the following: (1) Coonoor Peak, block I, compartments 4 and 7; (2) several fine specimens in Sim's Park, said to be about 30 years old (in 1912), the largest 114 ft. high and 11 ft. 1½ in. in girth; (3) a few specimens near Wrenn and Bennett's; (4) Springfield, compartment 11, six fine specimens along the road. It has been under trial in the Simla hills since 1909, and so far it has been found to do moderately well at 4,000–6,000 ft. It has been tried on the plains of northern India, but according to Mr. R. N. Parker it has been found quite unsuitable. Dr. Brandis in 1876 reported a number of trees, believed to be this species, in the Changa Manga plantation, the largest, then eight years old, being 56 ft. high and 27 in. in girth; probably, however, the species was not correctly determined. It has done well at Maymyo in Burma (3,500 ft.).

Var. *coccifera*, Hook. f., has been tried without success on the plains of northern India. It is said to be very frost-hardy, and to have passed through severe winters in England.

4. *Eucalyptus Andrewsii*, Maiden. Blackbutt or peppermint (of New England), white top.

A tall tree with rough somewhat fibrous bark on the stem, and red twigs. Timber not of the first class, with many gum veins. Common in New England, New South Wales, generally on metamorphic rocks, on rocky ground with poor soil. Stands a considerable degree of cold. Has been tried recently on the plains of northern India, but is unlikely to prove successful.

5. *Eucalyptus Baileyana*, F. v. M. Rough stringybark.

A tall tree with dense shady foliage, attaining 150 ft. in Australia. Bark very rough and fibrous. Wood very tough, suitable for tool handles. South-east Queensland, on poor somewhat sandy ridges near Brisbane. Has recently been tried on the plains of northern India, but so far does not show much promise.

6. *Eucalyptus bicolor*, A. Cunn. Black box.

Usually a small tree or only a shrub. Has recently been grown at Dehra Dun and has established itself well so far.

7. *Eucalyptus botryoides*, Smith. Bastard mahogany.

A tall straight-stemmed tree with handsome dark green dense shady foliage resembling that of a *Eugenia*. Bark furrowed, outside greyish brown, inside rusty brown. Wood hard, tough and durable, used for large beams and felloes of wheels. South Queensland, New South Wales, Victoria, Tasmania, in moist localities along river flats and in mountain ravines. Also on coast sands, where it is somewhat gnarled; it is one of the few eucalypts suitable for such localities. Will endure excessive soil-moisture, but the growth suffers if the ground is too swampy. Unsuitable for dry climates. It is among the species grown in the Nilgiris. Mr. R. Bourne gives the following localities: (1) Cairn Hill, block III; a felled tree measured 97 ft. in height; (2) Sim's Park, compartments 2 and 3, and in the Park itself. It grows well at Coonoor. It has recently been tried at Dehra Dun, and has established itself satisfactorily so far. It has been tried in mangrove swamps in the Andamans, but without success.

8. *Eucalyptus calophylla*, R. Br. Orange-flowered gum.

A moderate-sized to large tree with broad almost equilateral *Eugenia*-like leaves, and easily recognized from its very large urn-shaped fruits. Seedling leaves peltate at the base. Bark persistent, dark brown, deeply furrowed, reddish and rather stringy on young trees. Wood not durable in the ground, but useful for spokes and tool handles, for which purpose it is replacing hickory. South-west Australia, often in jarrah (*E. marginata*) forests. An extra-tropical tree, but has succeeded fairly well in some almost equatorial regions, as at Zanzibar. Requires a mild equable climate, and does not stand frost. It is grown in the Nilgiris. Mr. R. Bourne gives the following localities: (1) Coonoor Peak, block I, compartments 10, 33, and 36; (2) Rallia; (3) an aged specimen on the Coonoor *ghat* below Aravankadu on the north side of the road; (4) Botanical gardens, Ootacamund, No. 17, 4 ft. in girth and 66 ft. in height. It was introduced experimentally in 1909 in the outer Himalaya below Simla, and so far has done well below 4,000 ft. It has recently been tried on the plains of northern India, but has not shown much promise.

9. *Eucalyptus Cambagei*, Deane and Maiden. Bastard box.

A low stunted tree with somewhat fibrous bark. Timber of no use. Victoria and New South Wales. It has been tried in the Simla hills since 1909, and has done well at 4,000–6,000 ft. and moderately well at 6,000–7,000 ft. elevation.

10. *Eucalyptus capitellata*, Smith. Brown stringybark.

A moderate-sized to tall straight or sometimes stunted tree with rather dense dark foliage and deeply fissured stringy bark. Wood tough, strong, durable, and fissile, used for construction, posts, shingles, and fuel. New South Wales (south-west and north of Sydney on poor rocky country), Victoria (Gippsland over 500 ft. and in places along the coast), South Australia (Mount Lofty). It is stunted and forms dwarf forests on moist sandy ridges. Suitable for wet sandy soil, and is found sometimes on moist flats. Grown in the Nilgiris, Cairn Hill, block III; a tree 66 ft. in height was measured by Mr. R. Bourne. Has been tried on the plains of northern India, but has proved quite unsuccessful.

11. *Eucalyptus cinerea*, F. v. M. Argyle apple.

A handsome tree 40–50 ft. high, covered with a whitish bloom. Bark fibrous, thick. New South Wales. Has recently been tried on the plains of northern India, but does not show much promise.

Eucalyptus citriodora, Hook., see 36. *E. maculata*, Hook.

Eucalyptus coccifera, Hook. f., see 3. *E. amygdalina*, Labill.

12. *Eucalyptus coriacea*, A. Cunn. Syn. *E. pauciflora*, Sieber.

A moderate-sized tree, often with spreading branches, the branchlets more or less pendulous and often covered with a bluish bloom. Bark smooth, whitish grey. Wood rather soft and brittle; an excellent fuel. Victoria, New South Wales, Tasmania, from the lowest elevations up to near the snow-line in the Australian Alps. Is capable of standing rather severe frost, and grows close to glaciers, forming dwarf forests with *E. Gunnii* up to 5,500 ft. Has been tried in the Simla hills since 1909, and has done moderately well at 4,000–6,000 ft. Recently tried on the plains of northern India, but failed.

13. *Eucalyptus cornuta*, Labill. Yate.

A tree reaching fair dimensions in its home, but usually of small or moderate size, with slightly drooping foliage. Bark dark greyish brown, rough. Wood hard and elastic, used for shafts, boat ribs, and agricultural implements. South-west Australia. It thrives best in moist localities and does well in a humid climate, but can grow on poor soil. It can stand a considerable degree of frost, trees in Florida having withstood temperatures as low as 23° F. Under favourable conditions its growth is rapid. It has been grown in the Nilgiris (Botanical gardens, Ootacamund). It was tried without success about 1874-6 at Saugor in the Central Provinces. It has been tried in the Simla hills since 1909, and so far has done moderately well below 4,000 ft. It was reported in 1911-12 to be growing well in a rubber plantation at Kwanhla in the Amherst township, Burma.

14. *Eucalyptus corymbosa*, Smith. Bloodwood.

A tall tree, but often small and stunted. Bark persistent, rough, blackish grey, yellowish or reddish brown inside, that of upper branches smooth and reddish or whitish. Wood very hard and durable, but difficult to saw owing to the quantity of kino in it, and not a good fuel; used for piles and fence-posts. Queensland, North Australia, and New South Wales; the commonest eucalypt in Queensland (Bailey). There is a specimen, which has not grown to any size, in the Nilgiris in Sim's Park, Forest Lodge. It has been tried in the Simla hills since 1909, and has done moderately well above 6,000 ft. It has recently been tried without success on the plains of northern India.

15. *Eucalyptus corynocalyx*, F. v. M. Sugar gum.

A moderately tall tree with smooth bark and sweetish foliage which attracts cattle and sheep. Wood durable and very strong; said to be better than hickory. South Australia and Victoria. Growth not very rapid. Very drought-enduring, but grows best with a fair amount of moisture: intolerant of excessive soil moisture. It has been tried since 1909 in the Simla hills at various elevations, and so far has done moderately well from below 4,000 ft. to over 7,000 ft. It has recently been tried on the plains of northern India, but so far it does not show much promise.

16. *Eucalyptus crebra*, F. v. M. Narrow-leaved ironbark.

A moderate-sized or large tree with long narrow leaves, slender drooping branchlets, and small flowers and fruits. Bark rough, deeply furrowed, grey to almost black. Wood hard, tough, elastic and durable, used for posts, piles, bridges, and wagons. Queensland, New South Wales, and North Australia; often gregarious. Grown in the Nilgiris. Mr. R. Bourne gives the following: (1) Sim's Park; (2) below Cluny Hall, one tree measured 4 ft. 10 in. in girth and about 40 ft. in height; (3) Botanical gardens, Ootacamund, 7 ft. 6 in. in girth and 92 ft. in height. Now being experimented with further as a plantation tree in the Nilgiris, but the growth of the young trees is very slow, and success is not anticipated. Has been tried in the Simla hills since 1909, and so far has done only moderately well from 4,000 ft. upwards. Occasionally seen on the plains of northern India (Lahore, Amritsar, Kapurthala, Changa Manga, Saharanpur, Lucknow). On the plains the success is variable and the growth is slow in youth. Parker says the growth is slow for eucalyptus, but he records a tree 7 ft. in girth and fully 100 ft. high in Amritsar, the age of

which could not have been more than fifty years, and may have been considerably less. Line sowings along with field crops made at Dehra Dun proved successful in the earlier stages, a thick crop over 6 ft. high having resulted after two years : the plants did not suffer from frost, though in the very early stages many died of drought. The lines were, however, left untended and the plants suffered from overcrowding. Flowers December–January, Punjab (Parker).

17. *Eucalyptus delegatensis*, R. T. Baker. White ash.

A tall tree with reddish stringy bark. Wood fissile, pale coloured, light, esteemed for indoor work. South-eastern part of New South Wales, Victoria, on mountain ridges. Has been tried on the plains of northern India, but does not show much promise.

18. *Eucalyptus dives*, Schauer. Broad-leaved peppermint gum.

A moderate-sized tree with very aromatic leaves. Bark rough on the stem, smooth and yellowish on the branches. Timber of little value. New South Wales and Victoria, on poor rocky ground, usually on granitic rock. Has been tried recently on the plains of northern India, but gives little promise of success.

19. *Eucalyptus eugenioides*, Sieber. White stringybark.

A tall tree with dense dark shining *Eugenia*-like foliage and almost horizontal side branches. Bark thick and very stringy. Wood durable, fairly hard, easily worked, splits easily into shingles, slabs, &c. ; used also for fence-posts, building, sleepers, paving-blocks, flooring, and other purposes. Bark used for roofing and inner bark for mats and packing. South Queensland, New South Wales, and Victoria, growing gregariously for the most part on elevated poor ground but descending into sandy low land. The tree grows very well in the Nilgiris, reaching a size not attained in its natural home. Mr. R. Bourne gives the following : (1) Coonoor Peak, block I, compartments 4 (girth 12 ft. 5 in.) and 36 : (2) three or four fine specimens (one measured 113 ft. high and 10 ft. 7 in. in girth) in Botanical gardens ; (3) Sim's Park (girth 5 ft. 6 in. and 7 ft. 4 in., height 81½ ft. and 95 ft. respectively) ; (4) below Walthamstow ; (5) one fine specimen on the roadside near the lake below Woodcot ; (6) Keti, Snowdon, Aramby experimental plantations. It has been tried in the Simla hills since 1909, and so far has done moderately well at 4,000–6,000 ft. elevation. It has recently been tried on the plains of northern India, but does not give much promise of success.

20. *Eucalyptus eximia*, Schauer. White bloodwood, mountain bloodwood.

A fairly tall tree with dark foliage. Bark persistent, somewhat scaly or flaky, yellowish, verging into a brown or grey tinge. Wood soft, not durable, containing kino ; a good fuel. Has been tried in the Simla hills since 1909, and has done well so far at elevations below 6,000 ft. Has recently been tried on the plains of northern India, but does not promise well.

21. *Eucalyptus ficifolia*, F. v. M. Scarlet-flowered gum.

A small bushy tree with broad stiff leaves, dark above, paler below, and clusters of large handsome crimson flowers. A very handsome tree, planted mainly for ornament. South-west Australia. Has been extensively planted for ornament in the Nilgiris. Has recently been tried on the plains of northern India, but does not promise well.



FIG. 216 *Eucalyptus Globulus* coppice, 7 months old, with older coupes behind, Nilgiris.



FIG. 217 *Eucalyptus Globulus* coppice grassland type, 2 years old on left, 6 years old on right, the latter with mean girth 14.5 in., mean height 41 ft., volume per acre, 3,200 cubic ft. stacked, Aramby plantation Ootacamund

22. *Eucalyptus foecunda*, Schauer.

A shrub or small tree with dark green foliage and darkish smooth bark shedding in cartilaginous lamellae. Wood hard and elastic. Western Australia, chiefly on limestone, but also on sandy plains with a calcareous substratum. Grown in the Nilgiris, but rare ; Sim's Park (R. Bourne).

23. *Eucalyptus Globulus*, Labill. Blue gum.

A very large tree, with a tall straight clean bole when grown under forest conditions, but often tending to branch freely when grown in the open. Bark constantly decorticating in brown strips of varying length, showing the young smooth greyish or bluish white bark ; sometimes almost wholly persistent, and often rough at the base of the stem. The tree can be recognized by the quadrangular branchlets, the warty glandular calyx covered by a crown-shaped lid, and the characteristic leaves of seedlings and young coppice-shoots, which are opposite, sessile, cordate or cordate-ovate, covered with a bluish-white bloom and strongly impregnated with a gummy aromatic oil ; the stems of seedlings and young coppice-shoots are sharply quadrangular. Primordial leaves are also produced by adult trees which have been injured by fire or otherwise, and a burnt plantation has a characteristic silvery appearance. In the Nilgiris ripe seed may be collected about May, but the seed does not fall naturally until about July–August. Samples of Nilgiri seed gave 6,500 to 9,400 per oz. ; fresh seed gave the highest percentage of fertility, that kept for one year germinating fairly well, and that kept for two years germinating poorly. Fertile seed is produced at an early age : seed collected from coppice-shoots nine years old in the Nilgiris in 1912 showed a fertility of 47 per cent.

The wood is hard, heavy, and strong, and in its native home is considered durable, though not among the most durable of eucalypt timbers ; it is much used for house-building (joists, rafters, &c.), ship-building, carriage-building, &c. In the Nilgiris it has an indifferent reputation as timber, owing to its tendency to warp and split, but has proved to be fairly durable and is used for fence-posts. Possibly its poor reputation is due to some extent to the employment of timber from immature trees, for in some cases timber of fair quality has been yielded by large-sized trees. So far as Indian experience goes, however, there is not at present sufficient justification for planting the blue gum on an extensive scale as a timber tree. In the Nilgiris it is the principal source of fuel supply, and owing to its rapid growth and high yield it is eminently suitable for cultivation as a fuel tree.

The blue gum is a native of Tasmania, Victoria, and New South Wales, where it occurs chiefly in the humid regions, in valleys as well as on ridges and mountain slopes ; while common in most parts of Tasmania it is most plentiful in the south, but it does not ascend to alpine elevations. The blue gum has been more extensively planted than any other eucalypt in extra-tropical regions throughout the globe, its first introduction into southern Europe dating from the early part of last century. It was among the earliest of the eucalypts introduced into India, probably about 1843, when the first attempts were made to cultivate these trees in the Nilgiris.

The blue gum grows best in a moderately cool moist equable climate on deep fertile soil. It will endure excessive moisture, though not the equal of

E. rostrata in this respect: swampy ground, however, is not favourable to good growth. It is averse to calcareous and to saline soils. The seedlings are somewhat sensitive to frost and drought, and even in the Nilgiris, where the winter cold is by no means intense, they require to be protected from frost for the first year after planting out. The adult trees also do not stand severe frost or drought.

The blue gum has been tried from time to time in all kinds of localities throughout India, and from the experience gained it may be laid down that it is totally unsuitable for cultivation on the plains, or indeed at any elevation much below 4,000 ft. It has even been tried on coast sand in Madras, but needless to say the attempt was a complete failure. It has been planted in various parts of the Himalaya and has succeeded tolerably well in several places, particularly where the climate is not too severe, but it is very liable to breakage by snow, for which reason it is unsuitable for cultivation at altitudes where the snowfall is at all heavy. Prior to the abnormal frost of 1905 it was one of the commonest species grown at Abbottabad (4,000 ft.), but it was severely injured in the great frost, and many trees which had been killed outright were felled; there are now far fewer specimens there, and those which existed prior to 1905 are all injured. Experiments within recent years have shown that it grows well in the Simla hills at 4,000–7,000 ft. elevation. In Burma it has proved a failure at Maymyo (3,500 ft.) but has succeeded in the hills of the Ruby Mines district. It grows well at Shillong in Assam. It is in the Nilgiris, however, that this tree grows to the greatest perfection; it has been extensively planted at elevations varying from 5,000 to 8,300 ft., and is of paramount importance as a fuel-producing species. The climate of the Nilgiris has been described on pp. 558–9: being cool, equable, and moist it is an ideal one for the growth of the blue gum, while the red clayey soil overlying gneissic rock, and remarkably free from lime, appears to be specially favourable to the growth of the tree. The Nilgiri plateau is hilly to undulating, and consists largely of open grassy downs with *sholas*, or patches of dense evergreen forest of rather small-sized trees, occupying the more fertile hollows and ravines. Blue gum plantations have been formed both on grass-land and on *shola*-land, and the latter being more fertile the growth on this type of land is superior to that on the grass-land.

The blue gum plantations of the Nilgiris are worked mainly as simple coppice, the rotation adopted for some time past being ten years, but under the latest revised working plan¹ it has been raised to fifteen years, this rotation being likely to furnish a higher yield. Some of the plantations in the less accessible situations have remained as high forest, and these give some idea of the large dimensions attained by this tree. Coppice-with-standards was tried at one time, but the standards were found to interfere with the development of the coppice, and the system was therefore abandoned: some of the coppice-with-standards coupes have been allowed to grow up into high forest. The coppicing power of the tree is remarkable, numerous shoots being sent up both from the cambium round the top of the stool and from the periphery of the stool lower down, but chiefly from the latter; a callus forms over the top of the stool and may cover it completely in a few years.

¹ Working Plan for the Nilgiri Plantations, S. Cox, 1913.

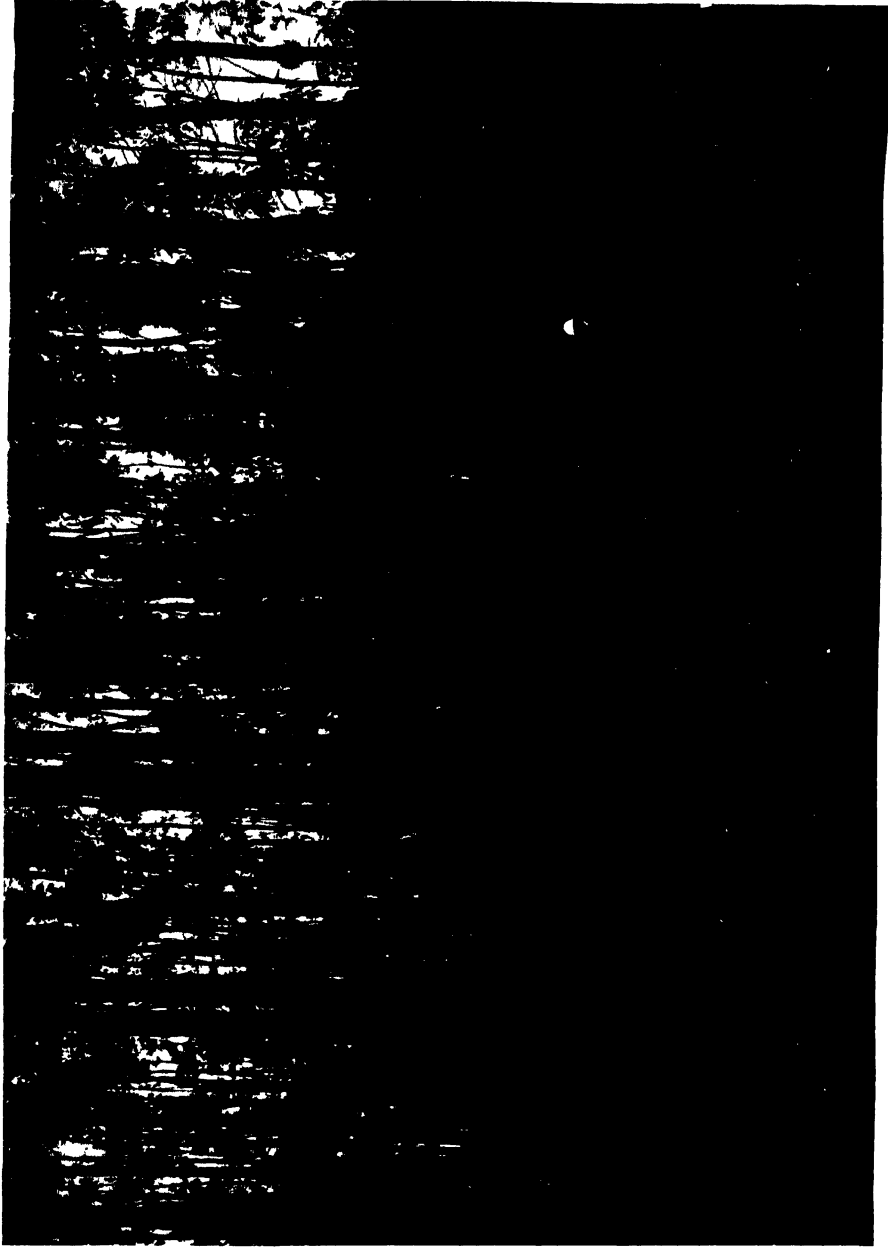


FIG. 218 *Eucalyptus Globulus* coppice, 8 years old grass-land type, showing comparative absence of undergrowth, mean girth 13.2 in., mean height 48 ft., volume per acre 4,000 cubic ft. stacked, Aramby plantation, Ootacamund.

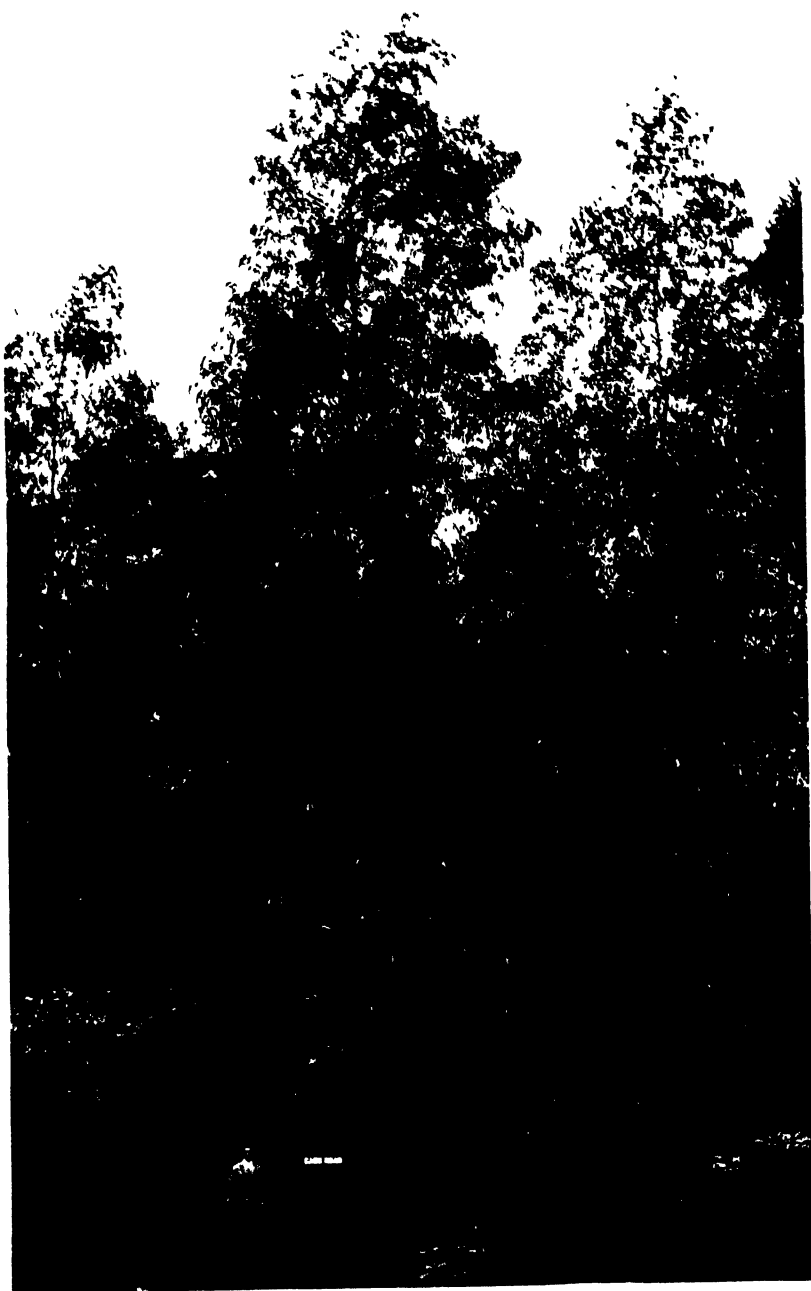


FIG 219. *Eucalyptus Globulus* coppice on *shola* land, age 4 years, height 45 ft., Coonoor Peak plantation, Nilgiris.

The vitality of the stools is considerable, for there are several coupes in the Nilgiris already in their fourth rotation, the last two rotations being ten years and the first generally longer, and the stools are apparently as vigorous as ever. The young coppice-shoots grow rapidly, reaching a height of 3 or 4 ft. or more in a few months. Fig. 216 shows a young coppice coupe, with the characteristic opposite pale bluish green primordial leaves, and Figs. 217 and 218 show older coppice coupes of the grass-land type, where there is little undergrowth except grass. The extremely rapid growth of coppice on *shola*-land is shown in Fig. 219, which represents coppice four years old and 45 ft. high. The young coppice-shoots thin themselves out rapidly, the average number per stool at five years of age being about 3, while even up to twenty-five years of age it varies ordinarily from 2 to 3.

The dimensions attained by individual trees in the Nilgiris may be exemplified by the following measurements made by me in 1912, it being understood that where the age is unknown none of the trees can be more than sixty-nine years old: (1) Woodside, isolated tree, age unknown, girth 19 ft. 2 in., height 138 ft.; (2) Tudor Hall, more or less isolated, age unknown, girth 12 ft. 7 in., height 150 ft.; (3) Brooklands plantation, age fifty years, trees in open crop, rather branchy, without much height-growth, maximum girth measured 15 ft. 1 in. In 1905 Mr. Cowley-Brown measured a tree on the Woodcot estate fifty-one years of age with a height of 166 ft. and a girth of 18 ft. 10 in.

Excellent growth is also shown in the high forest plantations of the Nilgiris, but as most of these have not been regularly thinned and have become congested, the girth increment and volume production are not what they would otherwise have been. Figs. 220 and 221 show two typical high forest plantations of very good quality, the former (Aramby) thinned and the latter (Mutinad) in need of thinning. In the former particularly the dimensions attained are remarkable; the age in 1912 was forty-nine years, the average and maximum girths were 6 ft. 9 in. and 11 ft. 6 in. respectively, and the average and maximum heights were 175 and 185 ft. respectively. The Aramby plantation consists of standards in former coppice-with-standards, and the trees have had free growing space throughout the greater part of their life.

A series of measurements in coppice and high forest crops was carried out in the same year in the blue gum plantations of the Nilgiris, and the results are summarized below.¹ The coppice figures may be regarded as giving a very fair general average, since they are based on numerous measurements in crops of various ages: the high forest figures, however, are given for individual crops only, since the number of crops of different ages was insufficient to give general averages, while the absence of regular thinnings in the past prevents a true idea of the development of most of the crops being arrived at:

¹ See my note on the Blue Gum Plantations of the Nilgiris, Ind. For. Records, vol. v, pt. ii, 1913.

1. *Eucalyptus Globulus* : girth and height measurements, Nilgiri plantations.

Age. years.	Mean girth.			Mean height.			Remarks.
	Grass- land.	Shola- land.	General average, shola- and grass-land.	Grass- land.	Shola- land.	General average, shola- and grass-land.	
	in.	in.	in.	ft.	ft.	ft.	
Coppice : general averages for stems of all sizes.							
5	9.0	..	9.8	30	..	33	
10	13.8	..	17.2	56	..	61	
15	..	..	21.4	..	..	74	
20	..	..	23.8	..	..	81	
25	..	..	25.2	..	..	85	
High forest : individual measurements of plantations, not general averages							
30	..	51.0	..	..	163	..	Mutinad, unthinned plot: dominant trees only.
30	..	47.0	..	..	143	..	Mutinad, thinned plot: average of trees left after thinning, including both dominant and dominated stems. Fig. 221 shows this crop before thinning.
35	42.0	..	..	115	..	..	Little Rallia : quality poor.
37	..	65.7	..	..	172	..	Yeppakuchy.
40	..	56.0	..	..	156	..	Rallia.
40	..	89.0	..	..	162	..	Coonoor Peak, compt. 9: standards in former coppice-with-standards.
42	..	58.0	..	..	158	..	Newman.
49	..	81.0	..	..	175	..	Aramby, II, 5: standards in former coppice-with-standards, see Fig. 220.

2. *Eucalyptus Globulus* : number of stems and volume production and increment per acre Nilgiri plantations.

Age. years.	No. of stems per acre.		Volume per acre.				Mean annual increment per acre, solid volume.			Remarks.
	Domi- nant only.	Total of all classes.	Grass- land.	Shola- land.	General average, grass- & shola-land.	Grass- land.	Shola- land.	General average, grass- and shola-land.		
			Solid vol. cub.ft.	Solid vol. cub. ft.	Solid vol. cub. ft.	Stacked vol. cub. ft.	cub.ft.	cub. ft.	cub. ft.	
Coppice : general averages.										
5	..	2,080	1,270	..	1,700	2,576	271	..	340	
10	..	880	3,230	..	4,850	7,348	360	..	485	
15	..	590	..	..	8,050	12,197	..	..	537	
20	..	470	..	..	11,200	16,970	..	..	560	
25	..	..	..	..	14,400	21,818	..	..	576	
High forest : individual crops, not general averages.										
30	94	526	..	14,212	..	..	..	474	..	Mutinad, unthinned plot.
30	174 ¹	628	..	15,822	..	..	..	527	..	Mutinad, thinned plot, before thinning : see Fig. 221.
35	..	720	..	10,212	..	..	..	291	..	Little Rallia : quality poor.
37	..	228	..	11,843	..	..	..	320	..	Yeppakuchy.
40	302 ²	580 ³	..	13,750	..	..	..	344	..	Eucalyptus
			..	3,992	..	..	..	100	..	Acacia Melanozylon
			..	2,090	..	..	..	52	..	Shola trees.
			Total	19,832	..	..	..	496	..	
40	40	190	..	14,010	..	..	..	350	..	Standards { Coonoor Peak, compt. 9: former coppice-with-standards.
			..	2,470	..	..	..	112	..	
			Total	16,480	..	..	..	462	..	
42	..	544	..	14,195	..	..	..	338	..	Newman.
49	51	..	..	12,704 ⁴	..	..	..	259	..	Aramby, II, 5 : standards former coppice-with-standards: see Fig. 220.

¹ Trees left after thinning: these include some dominated stems.² Includes acacia and shola trees.³ Eucalyptus only.⁴ 15,606 cub. ft. stacked.

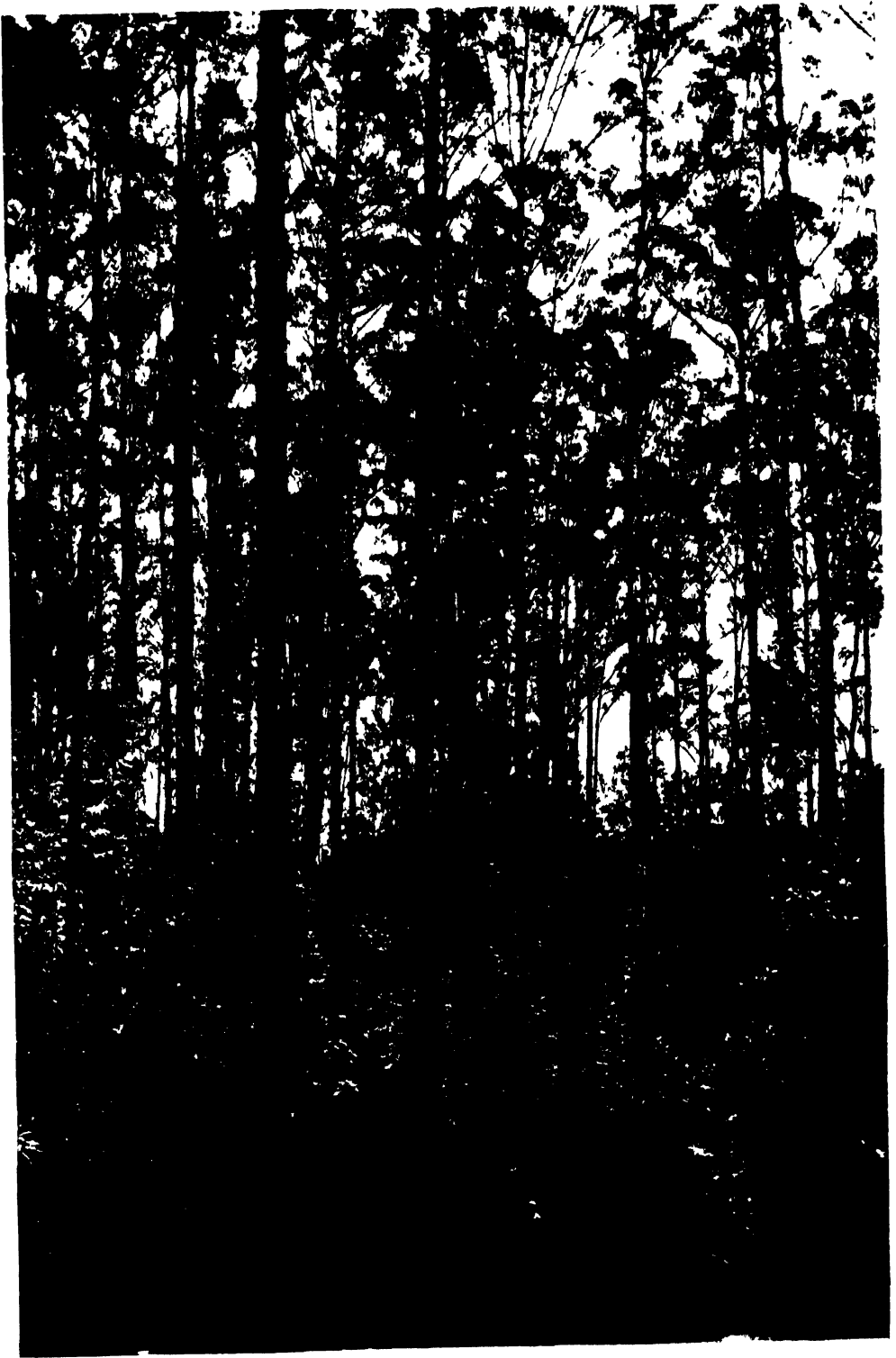


FIG. 220. *Eucalyptus Globulus* plantation on *shola* land ; age 49 years ; girth average 6 ft. 9 in , maximum 11 ft 6 in , height average 175 ft , maximum 185 ft. ; trees per acre 51, solid volume per acre 12,704 cubic ft., Aramby 11. 5, Ootacamund.



FIG 221. *Eucalyptus Globulus* high forest plantation, before thinning ; age 30 years ; after thinning, mean girth 3 ft 11 in , mean height 143 ft ; before thinning, stems per acre 628, solid volume per acre 15,822 cub ft , Mutinad plantation. Nilgiris

The following tables showing form factors and bark allowances have been compiled from the measurements made in 1912 :

3. *Eucalyptus Globulus* : form factors, Nilgiri plantations.

Height. ft.	Form factor.	Remarks.
30-50	0.55	Average of 179 felled trees. Form factor, f ,
51-70	0.54	obtained from the formula $f = \frac{v}{sh}$, where $v =$
71-100	0.53	volume of tree including bark, s = sectional area
over 100	0.51	at breast height, and h = total height of tree : s and v obtained from true sectional area, πr^2 .

4. *Eucalyptus Globulus* : allowance for bark thickness, Nilgiri plantations.

Total girth of tree including bark.	Average thickness of bark.	Average allowance for bark in girth measurements.
	in.	in.
Under 6 in.	0.1	0.6
6 in.-11 in.	0.25	1.6
1 ft.-1 ft. 11 in.	0.4	2.5
2 ft.-2 ft. 11 in.	0.6	3.8
3 ft.-3 ft. 11 in.	0.8	5.0
4 ft.-4 ft. 11 in.	0.9	5.7
5 ft.-5 ft. 11 in.	1.2	7.5
6 ft.-6 ft. 11 in.	1.3	8.0
7 ft.-7 ft. 11 in.	1.35	8.5
8 ft. and over	1.4	9.0

24. *Eucalyptus gomphocephala*, DC. Tooart.

A tall fairly shady tree. Bark persistent, rough and dark on old stems, greyish and smooth on younger stems and branches. Wood hard, strong, heavy, durable, difficult to split, used for ship-building, piles, bridge-construction, and other purposes. Western Australia, near the coast on limestone formation. Has been tried since 1909 in the Simla hills, and so far has done moderately well below 6,000 ft. Has recently been tried at Lahore and has succeeded fairly well hitherto, reaching a height of 16 ft. in four years.

25. *Eucalyptus gonioocalyx*, F. v. M. Mountain gum, spotted gum of Victoria.

A very tall tree, in rich valleys attaining 300 ft. in height, but often much smaller and tending to branch low. Bark persistent, wrinkled or fissured, but somewhat variable. Wood hard, tough, and durable, difficult to split, used for boat-building, construction, wheel-work, posts, &c. Victoria and New South Wales ; a rough-barked variety grows on low dry and stony ranges, and a taller variety with smoother bark is found in hilly country up to 3,000 ft., descending into wet valleys. Not usually gregarious. Has been tried since 1909 in the Simla hills, and has succeeded moderately well at elevations below 4,000 ft. Has been tried on the plains of northern India, but without success. It has recently been tried at Mercara in Coorg, and shows some promise.

26. *Eucalyptus Gunnii*, Hook. Swamp gum, cider gum.

A tree reaching large dimensions, but often crooked, and sometimes stunted. The leaves have not the strong aromatic odour characteristic of most eucalypts, and are therefore readily browsed by cattle and sheep. Bark constantly exfoliating in long strips, exposing the younger whitish bark. Wood

hard and of good quality, but straight stems are not always available ; usually splits with difficulty. South Australia, Victoria, New South Wales, and Tasmania, on alluvial flats, particularly in swampy places, but also on moist hill-sides and mountains, ascending in a dwarf state to 5,500 ft. A hardy species, standing a considerable degree of frost. It is cultivated in the Nilgiris ; Mr. R. Bourne gives the following : (1) Sim's Park, Forest Lodge ; (2) Botanical gardens, Ootacamund, No. 16, girth 4 ft. 2 in., height 63 ft. 6 in. ; (3) Cairn Hill, block III. It has been tried in the Simla hills since 1909, and has done well at elevations of 4,000–7,000 ft. and moderately well under 4,000 ft. It has been tried on the plains of northern India, but without success.

27. *Eucalyptus haemastoma*, Smith. White or scribbly gum.

A fairly tall slender erect tree with rather broad peppermint-scented leaves. Bark very white. Wood not of great value, not durable : a fair fuel. South Queensland, New South Wales, Victoria, and Tasmania, often on poor ground. Has been tried without success in the Simla hills and on the plains of northern India.

28. *Eucalyptus hemiphloia*, F. v. M. White or grey box.

A moderately tall tree with drooping foliage. Bark peeling off in long strips. Wood strong, hard, tough, close grained, and durable, used for posts, building, wheel-work, tool-handles, &c. South Queensland, sometimes extending into the tropics, New South Wales, Victoria, and South Australia, sometimes on flats but usually on rough dry hills or ridges. Not particular as to soil or climate. It is grown in the Nilgiris, where it is only a small tree. Mr. R. Bourne gives the following : (1) Sim's Park ; (2) below Cluny Hall, one tree measured 3 ft. in girth and about 35 ft. in height ; (3) St. Thomas's churchyard. It has been tried since 1909 in the Simla hills, and so far has done moderately well at elevations below 7,000 ft. It has recently been tried at Lahore, and has shown promise during the first few years, having reached a height of 22 ft. in four years.

29. *Eucalyptus Kirtoniana*, F. v. M.

A large tree with rough somewhat fibrous bark. According to Maiden this is a variety of *E. resinifera*, Smith, but whereas the latter cannot be grown on the plains, *E. Kirtoniana* has been grown successfully at Lahore and Saharanpur. According to Parker it does well on the plains provided it gets a good deal of moisture. There are a number of specimens in the grounds of the Punjab Club at Lahore. Flowers October–November (Parker).

30. *Eucalyptus Leucoxydon*, F. v. M. Victorian ironbark, white gum of South Australia.

A tree sometimes reaching a large size but usually crooked and of small size, with pendulous branchlets. Bark persistent, deeply fissured, very hard, and dark coloured ; a variety has the stem pale and smooth through the outer bark falling. The bark is rich in kino. Wood very hard, durable, and strong, used for wheel-work, shafts, railway sleepers, paving-blocks, axe-handles, &c. South Australia, New South Wales, and southern Queensland. The ironbark variety with persistent furrowed bark occurs chiefly on stony ridges or mountains of sandstone and slate formation. The white-barked variety occurs on alluvial plains around Adelaide. It has a wide range of climate and will grow even on poor soil. According to von Mueller it is one

of the best eucalypts for a moist tropical climate. There are specimens in the Nilgiris, but they have attained only small size. Mr. R. Bourne gives the following : (1) Government gardens, Ootacamund ; (2) Sim's Park, compartment 1; and (3) along Walker's Hill road, where it forms a handsome avenue. It has been tried since 1909 in the Simla hills, and has done well so far at elevations below 4,000 ft.

31. *Eucalyptus longifolia*, Link and Otto. Woolly butt.

A large handsome tree with drooping foliage which turns a pink colour. Bark persistent, greyish brown, fibrous, very thick. Wood more useful for fuel than for timber ; used for fence-posts. Victoria and New South Wales. It is grown in the Nilgiris, attaining a fair size. Mr. R. Bourne gives the following : (1) Sim's Park ; (2) Botanical gardens, Ootacamund : two trees measured, (i) girth 10 ft. 2 in., height 95 ft. 6 in., (ii) girth 7 ft. 6 in., height 113 ft. 10 in. It has been tried in the Simla hills since 1909, and has done well so far at elevations below 6,000 ft. It has recently been tried on the plains of northern India, but does not show much promise.

32. *Eucalyptus macrandra*, F. v. M.

A shrub or small tree with smooth bark, a native of Western Australia. Has been tried recently on the plains of northern India, but has not shown much promise.

33. *Eucalyptus Macarthuri*, Deane and Maiden. Paddy's River box.

A moderate-sized tree with rough bark. A native of New South Wales, preferring low swampy situations. Has recently been tried on the plains of northern India, but has not shown much promise so far.

34. *Eucalyptus macrocarpa*, Hook.

A large shrub, mealy all over with a whitish bloom, leaves opposite, sessile, lobed at the base. Flowers large and handsome with orange or crimson stamens. Western Australia, in dry scrub forests. Has recently been tried on the plains of northern India, but does not promise well.

35. *Eucalyptus macrorrhyncha*, F. v. M. Victorian stringybark, red stringybark.

A tree sometimes attaining fair dimensions but usually of moderate size, with handsome drooping foliage. Bark persistent, greyish brown, thick, deeply fissured, stringy, used for roofing. Wood hard, durable, easily split, used for shingles, fencing, and boarding. South Australia, Victoria, and New South Wales, on comparatively sterile ridges and ranges, often gregarious, frequently mixed with *E. obliqua*, not usually ascending to any great elevation. It is grown in the Nilgiris. Mr. R. Bourne gives the following : (1) Sim's Park ; (2) Botanical gardens, Ootacamund, No. 13, height 75 ft., girth 9 ft. 4 in. It has been tried in the Simla hills and also on the plains of northern India, but so far has proved unsuccessful.

36. *Eucalyptus maculata*, Hook. Spotted gum, including var. *citriodora*, Bailey (Syn. *E. citriodora*, Hook.), lemon-scented gum.

A tall straight clean-boled tree. Seedling leaves peltate at the base, rough with reddish hairs. Var. *citriodora* is distinguished from the normal variety by its strongly lemon-scented leaves. Bark smooth, whitish to reddish grey, falling off in patches, leaving an indentation where each patch was peltately attached and giving a spotted appearance to the stem. Wood strong, tough,

elastic, and durable, liable to warp in drying, easily split, used for wheel-work, carriage-building, tool-handles, ship-building, wood-paving, sleepers, &c. New South Wales and Queensland, the lemon-scented variety in Queensland. In its home it occurs usually on hilly ground. Outside its habitat it has been found incapable of resisting severe frost or excessive drought. It does best with considerable soil moisture, but will grow on fairly dry ground. In the severe frost of 1905 at Lahore young plants were killed but new shoots were sent up from the base; 'nursery plants at Dehra Dun are apt to be affected by frost in the winter unless protected. This is the species (var. *citriodora*) most commonly planted at Saharanpur and Dehra Dun, where it grows well and rapidly, though it runs to height rather than to girth. An avenue of this species was planted in the Forest Research Institute grounds at Dehra Dun in 1914. It also grows well at Lucknow and other stations of northern India. In the Punjab it is less common; seedlings are somewhat difficult to raise at Lahore. It is fairly common at Abbottabad. There are several specimens in the Nilgiris: Mr. R. Bourne gives the following: (1) Sim's Park, a specimen in the front of the Lodge; (2) in Mr. C. Mackenzie's garden at Ootacamund; (3) Botanical gardens, Ootacamund, girth 4 ft. 4 in., height about 70 ft.; (4) Sim's Park, compartment 1, in front of Forest Lodge; (5) a solitary specimen growing in the Moyar forest by the side of the Masnigudi-Tappacadu road, where it seems to be thriving fairly well. It was tried in 1913 at Mercara, Coorg, and so far has proved one of the best species experimented with, having attained a maximum height of 21 ft. and a maximum girth of 7 in. in three years. There are some trees at Maymyo in Burma, planted about 1893 and doing well. Flowers February-March, Punjab (Parker).

37. *Eucalyptus Maidenii*, F. v. M.

A tall straight tree with smooth white or bluish bark. New South Wales, at 1,000-2,000 ft., often on steep slopes. It has been tried since 1909 in the Simla hills, and has done well at 4,000-7,000 ft., and moderately well under 4,000 ft. elevation.

38. *Eucalyptus marginata*, Smith. Jarrah.

A large tree, averaging 100 ft. and reaching 150 ft. in height, sometimes buttressed at the base. Bark persistent, greyish brown, somewhat fibrous. Wood extremely durable, though not by any means the strongest of eucalypt timbers. It lasts for a long time under various conditions, not only in or on the ground, but also under water, and is said to be immune from the attacks of teredo in the sea. One of the best known timber trees in the world: wood largely used for piles, construction of all kinds, railway sleepers, paving-blocks, ship-building, &c. Jarrah sleepers have been imported into India in quantity for several years past. It occupies an area estimated at 8,000,000 acres in the south-western part of Western Australia, growing gregariously and at its best on hilly country on granite and ironstone, while on the sandy plains near the coast it is scattered and inferior in quality. Its region has an average rainfall of 30 to 40 in., and is peculiar in having regular winter rains from April to October. Where tried outside its habitat it has been found to be readily affected by frost, and to be unsuited for dry soils, requiring a moist but well-drained soil. Its introduction into India has been attempted from time to time, but so far as is known it has not yet been successfully established.

It has been tried and found quite unsuitable for the plains of northern India. At Lucknow it was found incapable of standing the rains. Brandis reported in 1876 that it was cultivated in the Nilgiris, but no specimens are known to exist there now. Seed was sown in 1909 in the Sanyasimalai plantation, North Salem, Madras, at an altitude of 4,000 ft., and the seedlings are reported to have done well during the first year, but no further reports are available.

39. *Eucalyptus melanophloia*, F. v. M. Silver-leaved ironbark.

A tree with a spreading crown and opposite sessile silvery leaves. Bark dark, rough. Wood hard and close grained. New South Wales, Queensland, in open country. This species is grown in Lahore, Changa Manga, Agra, and Saharanpur. When young it is apt to grow spindly and requires staking. Given sufficient water the growth is fairly fast; at Lahore young plants reached a height of 24 ft. in four years. It stands drought well. Flowers May-June, Punjab (Parker).

40. *Eucalyptus melliodora*, A. Cunn. Honey-scented gum, yellow box.

A moderate-sized tree, occasionally attaining large dimensions, with pendulous branches and slender branchlets. Bark brownish grey outside, yellow inside, more or less persistent. Wood yellowish, very hard, heavy, tough, and durable, used for wheel-work, posts, &c., but not very suitable for sawing into planks; an excellent fuel. Victoria and New South Wales, chiefly on ridges but descending into valleys. Will live on poor soil. Has been tried since 1909 in the Simla hills, and has done moderately well at elevations below 6,000 ft. Recently tried at Lahore, and has shown promise during the first few years, having reached a height of 25 ft. in four years.

41. *Eucalyptus microcorys*, F. v. M. Tallow-wood, wangee.

A large tree with reddish fibrous persistent bark. Wood very tough and durable, used for house- and ship-building, sleepers, wheel-work, &c. New South Wales and southern Queensland, on arid or sandy hills, on the coast side of the ranges. Comparatively rare in the Nilgiris: Sim's Park, a good specimen above the drive to Sim's Park Lodge (R. Bourne). Has been tried since 1909 in the Simla hills, and so far has done moderately well below 4,000 ft. Has recently been tried with some success at Saharanpur.

42. *Eucalyptus miniata*, Cunn.

A very ornamental tree with red flowers. Bark with external appearance and fracture resembling mica-schist. North Australia and Queensland. Nilgiris, in Sim's Park reserve (R. Bourne).

43. *Eucalyptus Muelleriana*, Howett. Yellow stringybark.

A tree often attaining 60 ft. in height, with straight massive bole and moderately spreading branches. Bark dark grey, fibrous, fissured. Wood of good quality, fissile, very durable. South Australia, Victoria, and New South Wales, usually on broken country, preferring the taluses of hills on moderately good soil and avoiding exposed situations (Maiden). It has been tried experimentally in the Simla hills since 1909, but has proved unsuitable for introduction on a large scale. It has also been tried recently on the plains of northern India, but does not show promise.

44. *Eucalyptus obcordata*, Turcz. Syn. *E. Platypus*, Hook.

A large shrub or small tree with broad leaves with wavy margins and very broad flattened flower-stalks. Bark smooth, greyish. Western Australia,

often forming almost impenetrable thickets. Has recently been tried on the plains of northern India, but gives little promise of success.

45. *Eucalyptus obliqua*, L'Hérit. Stringybark (South Australia and Tasmania), messmate tree (Victoria).

A very tall straight tree, attaining a maximum height of about 300 ft. Bark persistent, very fibrous, greyish outside, brownish red inside, rather soft. Wood not very durable but much used, owing to its abundance, for rough building purposes; very fissile, and extensively split into palings, shingles, &c. It is said to be an indifferent fuel, but this has not been found to be the case in the Nilgiris, where it is much used. The bark is used for roofing. South Australia, Victoria, New South Wales, and Tasmania, one of the commonest and most gregarious of the eucalypts, forming vast forests and extending to high but not to alpine elevations. It does not stand drought. After *E. Globulus* this is one of the commonest species in the Nilgiris, where it reaches large dimensions. It was tried at Saugor in the Central Provinces in 1874-6, but failed. It has been tried in the Simla hills at various elevations, but so far has not proved successful. It has failed hitherto on the plains of northern India, but recently it has given more promise of success in the early stages at Saharanpur.

Eucalyptus obtusifolia, DC., see 74. *E. virgata*, Sieb.

46. *Eucalyptus occidentalis*, Endl. Flat-topped yat.

A moderate-sized tree, attaining fairly large dimensions in favourable localities, but often little more than a shrub. Wood hard and strong, used for wheel-work. Western Australia, on clayey as well as on sandy soil, and also in wet places. Has recently been tried on the plains of northern India, but does not show much promise.

47. *Eucalyptus paniculata*, Smith. White ironbark.

A moderate-sized tree, attaining a height of 60 to 70 ft. Bark persistent, hard, rough, brown. Wood strong and very durable, much used for wheel-work, carriage-building, construction, sleepers, posts, &c. Chiefly in New South Wales in the coastal regions; also in Victoria. It can stand poor dry soil but not excessive heat or drought. There are specimens in the Nilgiris: Sim's Park, Forest Lodge (R. Bourne). It has recently been tried experimentally for plantation work in those hills, but so far the growth has been slow. It has been tried since 1909 in the Simla hills, and has done well hitherto at elevations below 4,000 ft. It has been grown for some time at Saharanpur, and there are a few trees at Changa Manga. Flowers September-October, Punjab (Parker).

48. *Eucalyptus patentinervis*, R. T. Baker. Bastard mahogany.

A large tree with angular branchlets and bark resembling that of some species of pine. New South Wales. Has recently been tried at Dehra Dun and has established itself, but has not been tried long enough to give definite results.

Eucalyptus pauciflora, Sieb., see 12. *E. coriacea*, A. Cunn.

49. *Eucalyptus pilularis*, Smith. Blackbutt.

A very large tree. Bark persistent at the base, greyish, fibrous, and rough, falling off in strips from the upper part of the trunk and branches. Wood hard, tough, and durable, used for building, ship-building, paving-blocks,

posts, &c. Queensland, New South Wales, and Victoria. Usually a mountain tree, but sometimes found on level ground along rivers; prefers a damp climate and a moist rich soil. It is not common in the Nilgiris, and does not attain the large dimensions reached in its native home: Mr. R. Bourne records a tree in Sim's Park 116 ft. high and 5 ft. 6 in. in girth. It is being further experimented with in the Nilgiris as a plantation tree, and so far has shown promise. It was tried at Mercara, Coorg, in 1913, and has done well so far. It has proved a failure in the Simla hills and on the plains of northern India.

50. *Eucalyptus piperita*, Smith. Sydney peppermint:

A moderate-sized tree, closely akin to *E. pilularis*, but with rougher bark extending to the branches. Wood said to be of inferior quality. Victoria, New South Wales, and Queensland, on rather poor ground. Has been tried in the Simla hills and on the plains of northern India, but without success.

51. *Eucalyptus Planchoniana*, F. v. M.

A moderate-sized tree with angular branchlets and flattened petioles. Bark persistent, more or less fibrous. Wood hard and heavy, used for house-building. Local in southern Queensland and New South Wales on sandy or rocky ridges. Has been tried since 1909 in the Simla hills and has done moderately well between 4,000 and 6,000 ft. elevation. Has recently been tried on the plains of northern India, but does not promise well.

Eucalyptus Platypus, Hook., see 44. *E. obcordata*, Turcz.

52. *Eucalyptus ptychocarpa*, F. v. M.

A moderate-sized tree with persistent greyish, wrinkled, somewhat fibrous bark, ornamental red flowers, and longitudinally ridged fruits. North Australia, along rocky streams and dry watercourses. Nilgiris: (1) Cairn Hill; (2) plentiful along the Walker's Hill road in Coonoor; (3) two or three fine specimens along the Ghat road from Aravankadu to Wellington (R. Bourne).

53. *Eucalyptus pulverulenta*, Sims. Silver-leaved stringybark.

A small scraggy tree with bluish white glaucous opposite sessile leaves and grey stringy bark. Wood brittle and twisted. Victoria and New South Wales. It has been grown to a small extent in the Nilgiris: Mr. R. Bourne gives the following: (1) Botanical gardens, Ootacamund; (2) Cluny Hall compound; (3) in a small plantation above the Sigur Ghat road, just beyond the junction of the Lascelles and Sigur roads.

54. *Eucalyptus punctata*, DC. Leather jacket, hickory gum.

A moderate-sized to large tree of spreading habit, with dark rough bark. Wood hard, tough, extremely durable, difficult to split, used for sleepers, fence-posts, wheel-work, building, &c.; a good fuel. New South Wales, usually in dry rocky places. It is grown in the Nilgiris (Sim's Park), and is receiving a further trial there as a plantation tree, showing good promise so far. It was tried at Mercara, Coorg, in 1913, and has proved successful in the early stages. It has been tried in the Simla hills since 1909, and hitherto has succeeded moderately well at elevations below 4,000 ft. Recently it has been tried along the railway between Lakhsar and Hardwar, and so far has done well on dry stony ground.

55. *Eucalyptus redunca*, Schauer. Wandoo, white gum (Western Australia).

A large tree with persistent smooth white bark. Wood hard, heavy,

durable, and very tough, much in demand for building, wheel-work, shafts, and tool-handles. Western Australia, forming extensive forests and more plentiful in the south-western parts of Australia than any species except *E. marginata*. It grows on hill slopes and on flats, being content with poor soil and even badly-drained ground. It is grown in the Nilgiris (Sim's Park), but is apparently uncommon (R. Bourne).

56. *Eucalyptus regnans*, F. v. M. See under 3. *E. amygdalina*, Labill.

Trees raised from seed imported under the name *E. regnans* have been under trial since 1909 in the Simla hills, and so far have done moderately well from 4,000 to 6,000 ft. elevation. This species has also recently been tried on the plains of northern India, but does not promise well.

57. *Eucalyptus resinifera*, Smith. Red mahogany.

A large tree, forming a tall straight clean bole. Bark rough, fibrous, persistent, decorticating on the branches, deep reddish brown in the young trees, changing to light grey and brown on older stems. Wood a rich red colour, strong and durable, used for piles, fence-posts, and building. The tree exudes kino. New South Wales and southern Queensland, not extending far inland. It prefers a moist semi-tropical climate, growing best on deep fertile ground; it will grow on a variety of soils, including poor gravel and sand, and is drought-resistant, but will not stand badly-drained swampy ground. It has proved exceptionally frost-resistant in Florida, having withstood temperatures of 19° F. without damage.¹ It is grown in the Nilgiris (Sim's Park), but is apparently rare (R. Bourne). It has recently been under trial in the Sanyasimalai plantation, North Salem, at an elevation of 4,000 ft. Its cultivation has been attempted in the Simla hills since 1909, so far with moderate success at elevations below 4,000 ft. It has been tried on the plains of northern India, but without success: a species introduced about 1865 and successfully cultivated at Lucknow under the name of *E. resinifera* was in 1876 finally determined to be *E. saligna*, Smith. Mr. R. N. Parker notes that for many years *E. rostrata* and *E. tereticornis* have been distributed from the Agri-Horticultural Gardens, Lahore, under the name of *E. resinifera*. This species has done fairly well at Maymyo in Burma (elevation 3,500 ft.). It was tried in the Andamans in 1914, and showed some promise after the first year. It has been found to do well in the neighbourhood of Mercara in Coorg, at 4,000 ft., in places sheltered from the force of the south-west monsoon, and it is proposed to plant such areas with this species for the fuel supply of Mercara.

58. *Eucalyptus robusta*, Smith. Swamp mahogany.

A moderate-sized to large tree with stout angular branchlets, large leaves, and somewhat spreading habit, making it suitable as a shade tree. Bark persistent, wrinkled, and somewhat furrowed, grey outside, sometimes turning a rusty colour. Wood rather brittle, difficult to split, fairly durable, used chiefly for building. New South Wales and Queensland, growing best in regions not far from the sea. This tree prefers moist situations, but will grow under a variety of conditions; it is particularly well adapted for thriving in badly-drained swamps, though not quite so tolerant of swampy ground as *E. rostrata*. It is somewhat sensitive to frost. The growth is fast. There are

¹ *Eucalypts* in Florida, R. Zon and J. M. Briscoe, U.S. Dept. of Agriculture, For. Serv. Bull., No. 87, 1911, p. 21.

a few trees in the Nilgiris. Mr. Bourne records two in Sim's Park: (1) girth 9 ft. 9 in., height 60 ft.; (2) girth 7 ft., height 80 ft. He states that no trace of this species can be found in the plantations, and where references to it are made in old records *E. obliqua* was evidently meant. It is grown in various parts of the plains of northern India and in the sub-Himalayan tract, where it is worth growing only in moist situations, being unsuccessful in even moderately dry places; young plants grow vigorously, but older trees often become misshapen and ugly. It was recently tried in mangrove swamps in the Andamans, but was unable to stand the salt water, it showed some promise during the first year on ground farther inland.

59. *Eucalyptus rostrata*, Schlecht. Red gum.

A large tree attaining a large girth, sometimes erect and symmetrical, but often irregular in shape, with drooping foliage. Bark smooth, ashy grey or whitish, often mottled with brown. Wood strong and very durable, used for railway sleepers, piles, bridge-construction, ship-building, wheel-work, and many other purposes; a very good fuel. Victoria, South Australia, Western Australia, New South Wales, Queensland, and North Australia; not in Tasmania. This is one of the most important timber trees of Australia, not only because of its useful timber, but also because of its wide range and great abundance. It has been introduced into various parts of the globe, and grows under a variety of climatic conditions and in various situations and soils, preferring moist alluvial valleys and river-banks, but enduring considerable drought. It is particularly well adapted for growing in moist swampy localities, being probably unsurpassed by any other eucalypt for this purpose. It stands a considerable degree of frost as well as of heat; in California it endures minimum temperatures of 15° to 20° F., and maximum temperatures of 110° to 115° F.¹ The growth is rapid, though not equal to that of *E. Globulus*.

It is grown in the Nilgiris, where it coppices badly; Mr. R. Bourne gives the following localities: (1) Cairn Hill, block I, compartment 3 in the swamp, and block II, compartments 4 and 5; (2) Aramby, in a few places. It was tried without success at Saugor, Central Provinces, in 1874-6. It was sown in 1909 in the Sanyasimalai plantation, North Salem (elevation 4,000 ft.), and did well in the early stages. It has been tried since 1909 in the Simla hills, and has done well up to date at elevations below 4,000 ft. It is one of the species grown at Abbottabad (4,000 ft.). On the plains of northern India it thrives well and grows rapidly. In the Changa Manga plantation this species and *E. tereticornis* have proved more successful than any other eucalypt hitherto tried, and when once established they can hold their own against the mulberry. At Maymyo, Burma (elevation 3,500 ft.), it has done better than any other species tried so far; the fine avenue in the Maymyo bazaar consists chiefly of this species. It has recently been tried in the Andamans, and has shown promise in the early stages. It is cultivated at Calcutta, Poona, and other low elevations. Flowers May-June, Punjab (Parker).

60. *Eucalyptus rubida*, Deane and Maiden. Candle-bark.

A tree with smooth glaucous bark, often with reddish patches, the outer layer falling off in ribbons. New South Wales and Victoria. It has recently been tried on the plains of northern India, but has not shown much promise.

¹ *Eucalyptus, its History, Growth, and Utilization*, C. H. Sellers, California, 1910.

61. *Eucalyptus rudis*, Endl. Swamp gum, flooded gum.

A moderate-sized to large tree with leaves rich in oil. Bark greyish, usually rough and persistent, but sometimes flaking off and leaving the trunk smooth. Wood useful for fuel, and also used for posts. Western Australia, on river-banks and around swamps. In California it has proved remarkably hardy to heat and cold, enduring minimum temperatures of 15° to 18° F., and maximum temperatures of 110° to 118° F.¹ It has been tried since 1909 in the Simla hills, and so far has proved fairly successful at elevations below 6,000 ft. Within recent years it has been tried on the plains of northern India and in the sub-Himalayan tract (Lahore, Saharanpur, Lucknow, Dehra Dun), and has proved extraordinarily successful. A tree situated in the worst plot of land in the Government Agri-Horticultural Gardens, Lahore, attained a height of 50 ft. and a girth of 2 ft. 5 in. in four years.² This tree formed one of a row of trees growing vigorously in a patch of saline soil in which the salt-weed (*Suaeda fruticosa*) could hardly grow, and where all ordinary plants were incapable of living; at three years of age they averaged 30 ft. in height. Mr. R. N. Parker,³ in describing these plants at Lahore, notes that for satisfactory growth, *E. rudis* apparently requires a very dry climate; the Lahore plants received constant irrigation since they were planted, but an abundance of water is not essential, as in the Kot Lakhpat plantation near Lahore this species is growing remarkably well with only moderate irrigation and with long intervals between successive watering. This species is doing well at Lucknow, and is reported to be thriving on swampy ground between Lakhsar and Hardwar.⁴ Flowers October to February (Parker).

62. *Eucalyptus saligna*, Smith. Grey gum.

A tall straight tree with deciduous rather thick grey bark. Wood very hard, tough, and close grained, used for ship-building, carpentry, &c. New South Wales and southern Queensland, often plentiful on ridges, but also frequent along banks of streams. Said to prefer a deep moist soil and to be sensitive to drought. In Florida a tree has withstood temperatures of 22° F. without serious injury, another tree in an exposed situation was bent and dwarfed by the wind.⁵ It is grown in the Nilgiris (Sim's Park). It has been tried in the Simla hills since 1909, and has done moderately well above 4,000 ft. It grows well on the plains of northern India, but apparently in most of the older reports the name *E. saligna* has been applied to totally different species. On the other hand, at Lucknow specimens of what were at first considered to be *E. resinifera* were in 1876 finally determined to be *E. saligna*; one tree was reported in 1877 to have attained a height of 45 ft. and a girth of 3 ft. 9 in. at 3 ft. from ground-level in ten to twelve years. Recently this species has again been tried at Lucknow, and so far it has proved very promising. It has recently been tried at Mercara in Coorg, and shows some promise. Mr. R. N. Parker⁶ notes that on the Punjab plains he has seen this species only in Amritsar, where there are a number of specimens growing remarkably well; seedlings sown in Lahore in 1912 died off in large numbers during the monsoon, but the survivors were quite healthy and vigorous the following year. The

¹ Sellers, *loc. cit.*, p. 73.² Garden Report, 1914-15.³ Ind. Forester, xi (1914), p. 452.⁴ Report Gov. Bot. Gardens, Saharanpur, 1915-16.⁵ Zon and Briscoe, *loc. cit.*, p. 26.⁶ Ind. Forester, xxxix (1913), p. 85.

plants reached a height of 12 ft. in three years. Flowers May, Punjab (Parker).

63. *Eucalyptus siderophloia*, Benth. Sydney ironbark. (The name broad-leaved or large-leaved ironbark is the one more correctly applicable to var. *rostrata*, the young leaves of which are often 2 to 6 in. wide).¹

A large tree with a straight stem. Bark persistent, dark brown to nearly black, thick, deeply furrowed. Wood close grained, very hard, heavy and durable, largely used for building, bridge-construction, railway sleepers, wheel-work, and other purposes for which great strength is required; this is the principal ironbark tree in its native home. New South Wales and southern Queensland. A tree in Florida about ten years old measured 55 ft. in height and 13.7 in. in diameter; it was growing on dry soil and had withstood a temperature of 22° F.² In the Nilgiris there is a small plantation beyond Forest Lodge in Sim's Park, where this species is growing well (R. Bourne). It is now being experimented with further as a plantation tree in those hills, and has hitherto shown fairly rapid growth. There is a specimen doing well in the Changa Manga plantation near Lahore. It has been tried at Lucknow since 1912, and so far has done well. At Lahore seeds of this species were sown in 1911, and the plants reached a height of 11 ft. 7 in. in three years, but failed in the fourth year. Flowers April, Punjab (Parker).

64. *Eucalyptus Sideroxylon*, A. Cunn. Red ironbark, Victoria ironbark.

A moderate-sized or large tree with narrow silvery leaves and hard, rough, dark-coloured bark. Wood dark red, very hard, heavy, strong, and durable, used for railway sleepers, beams and girders, shafts and wheel-work. New South Wales, Victoria, and Queensland, usually on poor sterile ranges. In California it endures minimum temperatures of 16° to 20° F., and maximum temperatures of 110° to 112° F.³ It was tried without success at Saugor, Central Provinces, about 1874-6. It is reported to have done well in the Kumaun hills, and is one of the species grown at Abbottabad, where it survived the severe frost of 1905. It has been tried since 1909 in the Simla hills, and has done moderately well between 4,000 and 6,000 ft. It has been tried at Changa Manga, but does badly; the heartwood of the trees becomes eaten by white ants. Not suitable for the plains. In India it tends to form a crooked bole and to produce large branches. Flowers September, Punjab (Parker).

65. *Eucalyptus Sieberiana*, F. v. M. Yohut, mountain ash.

A large tree attaining 120 ft. in height. Bark dark brown or grey, deeply furrowed, red and scaly on young trees, smooth and pale on branches. Wood tough and elastic, not durable when exposed to the weather, used chiefly for ship-building, tool-handles, and carriage-building; a good fuel. South Australia, Victoria, New South Wales, and Tasmania, frequent on poor barren ground or sandy soil on rocky and stony mountain ranges, ascending on southerly aspects to 5,000 ft. This tree has been grown to some extent in the Nilgiris, where it is found almost always as coppice; older trees are of rather crooked growth. Mr. R. Bourne gives the following localities: (1) Cairn Hill, block II, compartments 1, 4, 11, 12, 13, 14, and 19, and block III; (2) Aramby, block II, compartments 13 and 14; (3) Baikie, compartments 3 and 5. It has been

¹ Bailey, Queensland Woods.

² Zon and Briscoe, *loc. cit.*, p. 27.

³ Sellers, *loc. cit.*, p. 73.

tried without success in the Simla hills and also on the plains of northern India.

66. *Eucalyptus Smithii*, R. T. Baker. White top, gully ash.

A tall tree with furrowed dark grey bark, smooth on the branches and upper bole. New South Wales, in the south coastal districts. Has recently been tried on the plains of northern India, but does not show much promise.

67. *Eucalyptus stellulata*, Sieb.

A small or moderate-sized tree with dense foliage and rough dark somewhat scaly bark, smooth and greenish on the branches. Wood a good fuel, but not much in request as timber. Victoria and New South Wales, along elevated river valleys or flats and on mountain sides up to the sub-alpine zone. Has recently been tried on the plains of northern India, but does not show much promise.

Eucalyptus stricta, Sieb., see 74. *E. virgata*, Sieb.

68. *Eucalyptus Stuartiana*, F. v. M. Buṭ-but, apple-scented gum, Stanthorpe box.

A small to moderate-sized tree with drooping branchlets, and often with a twisted stem; bark persistent, fibrous, soft. Wood hard, tough, and durable. South Australia, Victoria, New South Wales, and Tasmania, on sandy and moist tracts, often on low ridges, sometimes on river flats, where it reaches a fair size; Queensland, on poor ground. It is grown in the Nilgiris (Cairn Hill, block III), where, according to Mr. R. Bourne, several of the trees have been killed by cattle and deer, which tear off and eat the succulent bark. It has been tried in the Simla hills since 1909, and so far has done well between 4,000 and 7,000 ft., and moderately well below 4,000 ft. elevation. It has been tried on the plains of northern India, but has proved quite unsuitable.

69. *Eucalyptus tereticornis*, Smith. Grey gum, forest red gum.

A tall handsome tree. Bark smooth, whitish or greyish, more or less deciduous. Wood reddish, close grained, tough, and durable, used for building and many other purposes. Victoria, New South Wales, Queensland, never far from the littoral regions, and usually found on fertile ground on humid flats, around swamps and lakes, or along watercourses, never on saline ground or along salt-water streams; stunted if found on rocky exposed localities. Under favourable conditions the growth is rapid. It does well on sandy soil, even if comparatively dry, but not on hard dry soil. In Florida trees have withstood temperatures of 20° and 22° F., but were frozen back at 19° F., although not permanently injured; in California it is said to endure lower temperatures and to withstand drought well, while in Provence and Algeria it has grown well on low, marshy tracts where the soil is deep, and in Brazil on inundated soil where *E. rostrata* could not be grown successfully.¹ The tree coppices excellently. At Abbottabad coppice-shoots attained in one year a height of 15 ft. and a girth of 7½ in., and in 5½ years a girth of 22 in. At Dehra Dun the branches have been found rather liable to breakage by wind. Parker says it was severely damaged by frost at Abbottabad in 1905, but not so much as *E. Globulus* or many of the indigenous trees.

The tree has been grown in the Nilgiris; Mr. Bourne mentions a specimen 6 ft. 2 in. in girth and 60 ft. high in Sim's Park, and adds that a whole planta-

¹ Zon and Briscoe, *loc. cit.*, p. 28.

tion of this species is said to have been planted by Mr. Gamble at the back of the Range Lodge, but either it died out or there was a mistake in identity. This species is probably the most successful one tried so far at low elevations in India, growing well even at Bombay. On the plains of northern India it is one of the best species, doing well in the United Provinces and the Punjab as far north as the Rawalpindi district, and also in Hazara. The growth is very rapid; of trees raised from seed sown about 1877 at Unah, Hoshiarpur district, measurements of some of the finest in 1893 (aged about sixteen years) were as follows : ¹

1.	Girth at 4 ft. from ground,	5 ft. 7 in.	height,	115 ft.
2.	„	„	5 ft. 5 in.	„ 115 ft.
3.	„	„	5 ft. 1 in.	„ 115 ft.
4.	„	„	5 ft. 6 in. ;	„ 75 ft.

Parker mentions a tree on poor gravelly soil near Haripur, Hazara, six years from seed, which measured 30 ft. in height and 2 ft. 5 in. in girth. There are a few good specimens in the Kaunli garden at Dehra Dun. It is the commonest species at Abbottabad. It has been tried in the Simla hills since 1909, and so far has done very well below 4,000 ft. and moderately well from 4,000 to 6,000 ft. It was tried in 1914 in the Andamans, and was one of the few species which showed any promise after the first year. Flowers January to April, Punjab (Parker).

70. *Eucalyptus trachyphloia*, F. v. M. White bloodwood.

A moderate-sized tree with dense foliage. Bark persistent, rough, fibrous, or almost woody inside. Wood hard, heavy, and durable. Southern Queensland, on poor hilly country, chiefly on sandstone. Said to be suitable as a shade tree in hot dry localities. Has been recently tried on the plains of northern India, but so far does not show much promise.

71. *Eucalyptus umbra*, R. T. Baker.

A tall tree with dark coloured stringy bark. Timber not very durable. New South Wales. It has recently been tried on the plains of northern India, but has not shown much promise.

72. *Eucalyptus urnigera*, Hook. f.

A small to moderate-sized tree with spreading branches and drooping branchlets. Bark smooth, pale brown. Tasmania, in alpine districts. It has recently been tried on the plains of northern India, but has proved quite unsuitable.

73. *Eucalyptus viminalis*, Labill. Manna gum.

A large handsome tree with drooping foliage. Bark partly persistent on the lower part of the stem, rough, wrinkled, and brownish, decorticating on the upper parts and on the branches, leaving the young smooth, bluish white bark, which when rubbed gives off a white powder. Wood fairly strong but not very durable, used for rough building, shingles, and rails. South Australia, Victoria, New South Wales, Tasmania, reaching large dimensions in deep forest glens, but found chiefly in open land, accommodating itself to poor and even sandy soil. It grows in the Nilgiris, sometimes attaining a fair size. Mr. R. Bourne gives the following distribution : (1) Sim's Park on lake

¹ W. Coldstream in Ind. Forester, xix (1893), p. 381.

edge; (2) below Cluny Hall; (3) some fine specimens at Snowdon Hall lining the Kotagiri road above the Snowdon ponds; (4) Sim's Park, compartment 1, above Forest Lodge. Measurements at Snowdon Hall gave girths of 8 ft., 9 ft. 6½ in., 10 ft. 7 in., and 13 ft. 4 in.; also girth 9 ft., height 124 ft. 6 in., girth 10 ft. 0½ in., height 128 ft. 6 in. It was tried without success about 1874-6 at Saugor, Central Provinces, and recently on the plains of northern India. It has been tried since 1909 in the Simla hills, and so far has done well at elevations of 4,000-7,000 ft. In Burma it has proved successful at low elevations.

74. *Eucalyptus virgata*, Sieb. Syn. *E. stricta*, Sieb.; *E. obtusifolia*, DC.

A large shrub, usually with very narrow leaves. New South Wales, ascending to high elevations in the mountains. Has been tried without success on the plains of northern India.

3. BARRINGTONIA, Forst.

Species 1. *B. acutangula*, Gaertn.; 2. *B. racemosa*, Bl.

1. *Barringtonia acutangula*, Gaertn. Vern. *Injar*, *neora*, Hind.; *Hijal*, Beng.; *Tivar*, *piwar*, Mar.; *Kanapa*, Tel.; *Kyi*, *kyeni*, Burm.

A moderate-sized evergreen tree with dark rough bark, obovate leaves clustered at the ends of the branches, and long pendulous racemes of flowers with bright red stamens. The wood is used for boat-building, cabinet-making, and other purposes; the bark is rich in tannin, and is used to intoxicate fish. The tree is fairly common in many parts of India and Burma, in the sub-Himalayan tract from the Ganges eastwards, Bengal, Chota Nagpur, the Indian Peninsula, and Burma; also in Ceylon, the Malay Archipelago, and northern Australia. It is always found along the banks of streams, round the edges of swamps and in similar moist places. It is a familiar tree in the swamps of the sub-Himalayan tract, and is also common near the coast, though not found in mangrove swamps.

The leaves fall and the new leaves appear from February to April; the flowers appear chiefly from March to May, and the fruits ripen in July-

August. The fruits are oblong, quadrangular, 1 in. or more in length, and about ½ in. in diameter. The seed is exalbuminous and solitary, and the embryo thick

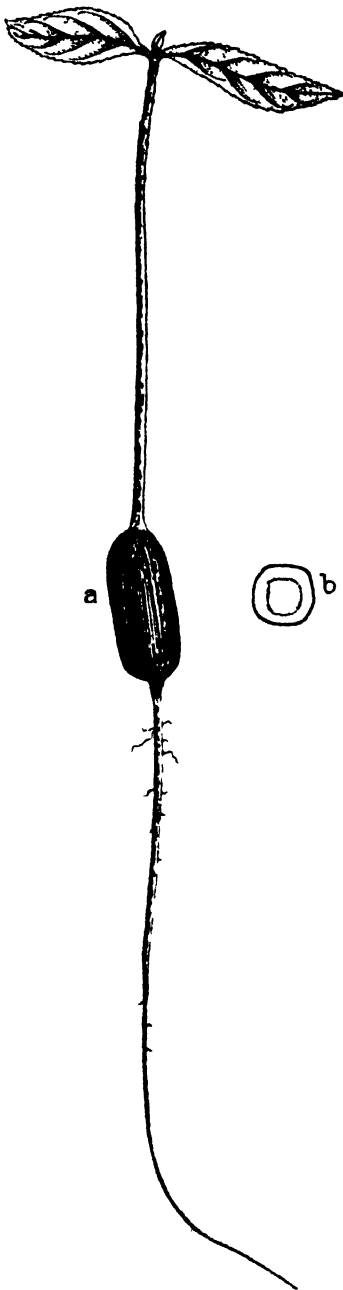


FIG. 222. *Barringtonia acutangula*. Seedling $\times \frac{1}{2}$.

a, swollen hypocotyl; b, cross-section of hypocotyl.

and fleshy with rudimentary scale-like cotyledons. The fruits fall into the moist often muddy ground around the trees, and seedlings may be found in quantity growing in soft mud. Germination is peculiar. The shoot is developed from one end of the fleshy embryo and the root from the other end. A long taproot descends into the mud and the original fleshy portion of the embryo enclosed in the testa, and retaining the shape of the fruit, persists until the seedling attains a fair size. This fleshy portion resembles a tuber, and if cut across shows a ring of vascular tissue like that of a carrot (see Fig. 222). The function of this tuberous growth is presumably to store up nutriment in order to feed the young plant in the dry season when the mud dries up.

The tree is often planted for ornament. It is also suitable for planting in swampy ground where few other species will grow; probably direct sowings would prove most successful. It is ordinarily frost-hardy, but at Lahore it was slightly affected in the severe frost of 1905. In the abnormal drought of 1907 and 1908 it suffered along the banks of streams and swamps in Oudh when the water dried up.

2. *Barringtonia racemosa*, Bl.

A species with much larger flowers and fruits than the preceding. It also grows by streams and in swampy ground, and is indigenous along the west coast of the Indian Peninsula, in the Sundarbans, Andamans, Ceylon, the Malay Peninsula, and Polynesia.

4. *CAREYA*, Roxb.

Careya arborea, Roxb. Vern. *Kumb*, *kumbi*, Hind., Beng.; *Kumbia*, Mar.; *Kaval*, Kan.; *Ayama*, Tam.; *Gadava*, Tel.; *Banbwè*, Burm.

A moderate-sized to large deciduous tree with large obovate leaves clustered at the ends of the branches. Bark dark grey, fissured, red and fibrous inside. The wood is durable, especially under water, and is used for building, carts, furniture, &c.; the bark gives a good rough cordage-fibre.

DISTRIBUTION AND HABITAT. The tree is found sporadically throughout the greater part of India and Burma, but not in the driest regions. It is very typical of savannah lands, where owing to its fire-resisting capacity it is able to survive and to regenerate, along with other fire-resisting species such as *Dillenia pentagyna*, *Eugenia operculata*, and *Bombax malabaricum*. When fire-protection is introduced more tender species take possession of the ground, but the old and often branchy savannah trees persist scattered in the new growth.

Careya arborea is a familiar tree in the sal forests and in the grassy blanks so common in them. In Burma it is commonest in the lower mixed forests of the plains and in the open savannah tracts. Generally it is characteristic of the moist types of mixed deciduous forest, and not of the drier types.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The tree is leafless early in the hot season, the new leaves appearing in March–April. The leaves turn red in the cold season before falling. The clusters of large pink and white flowers appear with the new leaves in April–May, and the fruits ripen about June–July: they are green, globose, about 3 in. in diameter, containing several seeds embedded in a fleshy pulp, and fall soon after ripening. The seeds are exalbuminous, but have a large embryo similar in structure to that of *Barringtonia*: they often germinate within the fruit as it lies on the ground.

SILVICULTURAL CHARACTERS. The tree stands a fair amount of shade. In the abnormal drought of 1907 and 1908 in the sal forests of Oudh it proved to be decidedly hardy. It coppices well. It is very subject to damage by browsing, coppice-shoots in particular being greedily eaten by cattle and deer. As already noted, it is very fire-resistant.

RATE OF GROWTH. The following statistics regarding the rate of growth are available from sample plot measurements in sal forest :

Careya arborea : girth increment in high forest sample plots.

Province.	Forest division.	Locality.	No. of years under measurement.	No. of trees under measurement.	Girth classes.	Mean annual girth increment for period.
					ft.	in.
United Provinces	Saharanpur	Malowala	12	4	1-2	0.20
	Lansdowne	Chaukhamb	17	6	1-8	0.32
	"	Jogichaur	12	2	1-3	0.18
	"	Rehar	19	1	1-3	0.05
Central Provinces	Balaghat	Baihar	8	1	1-2	0.44

Ring-countings by Mr. D. A. Thomson in respect of seventeen trees in the Supa fuel reserves, North Kanara, Bombay, gave the following results :¹

Age in years	5	10	15	20	25	30	35	40	45	50	55	60	65
Mean diameter (inches)	1.05	2.02	3.07	4.09	5.08	5.90	6.84	7.74	8.46	9.38	10.14	10.94	11.71

Coppice-shoots grow fairly rapidly. Measurements in 1911 in two separate coupes, each two years old, in the Tikri forest, Gonda, United Provinces, showed average heights of 11 and 12 ft. as compared with 10 and 7.6 ft. respectively for sal in the same coupes. Measurements made in 1886 by Mr. A. F. Broun in two coupes, each eight years old, in the Bullawala coppice, Dehra Dun, gave the following results :

Careya arborea : growth of coppice, Bullawala, Dehra Dun.

Age. years.	Mean height.		Mean girth.	
	<i>Careya.</i> ft.	Sal. in.	<i>Careya.</i> in.	Sal. in.
8	30 0	13 2.0	9.0	7.1
8	10 4	16 2.5	5.7	8.3

Mr. H. A. Gass recorded in 1898-9 an average height and girth of 10 ft. and 7 in. respectively, with nine shoots per stool, in a coppice coupe three years old in Kadike block, South Canara, Madras.

5. PLANCHONIA, Bl.

Planchonia andamanica, King.

An evergreen tree of the Andamans, occurring in evergreen or semi-deciduous forests in association with *Dipterocarpus* spp., *Hopea odorata*, *Mimusops Elengi*, *Artocarpus Chaplasha*, *Pterocarpus dalbergioides*, *Albizia Lebbek*, *Terminalia bialata*, *Lagerstroemia hypoleuca*, and other species. The wood is hard, durable, and of good quality, and promises to become an important timber ; the tree deserves study from a silvicultural point of view.

¹ Working Plan for the Supa Fuel Reserves, 1906.

ORDER XXIX. LYTHRACEAE

This order contains a number of important Indian timber trees, chiefly belonging to the genus *Lagerstroemia*.

Genera 1. *LAGERSTROEMIA*, Linn.; 2. *DUABANGA*, Ham.; 3. *SONNERATIA*, Linn. f.; 4. *WOODFORDIA*, Salisb.; 5. *PUNICA*, Linn.

1. *LAGERSTROEMIA* Linn.

This genus contains eleven Indian species of trees and perhaps a twelfth, *L. indica*, Linn., a well-known garden tree which is indigenous in China and possibly in the Shan hills in Upper Burma. To this genus belong some important Indian timber trees, most of which are very ornamental owing to their large showy flowers. The silviculture of these trees is at present imperfectly understood. The fruit is a capsule containing many winged, usually small light seeds, which, in all the species studied so far, are uncertain in their germinative power, a large proportion being as a rule unfertile. *L. indica* and *L. Flos-Reginae* are known to be capable of propagation from cuttings, and the same may possibly be the case with other species.

Species 1. *L. parviflora*, Roxb.; 2. *L. Flos-Reginae*, Retz.; 3. *L. tomentosa*, Presl.; 4. *L. lanceolata*, Wall.; 5. *L. macrocarpa*, Kurz; 6. *L. hypoleuca*, Kurz.

1. *Lagerstroemia parviflora*, Roxb. Vern. *Dhaura*, *lendia*, Hind.; *Sidha*, Hind., Beng.; *Lende*, *bondga*, Mar.; *Chenangi*, Tel.; *Zaungbalè*, *kyettawsa*, U. Burm.

A large, in poor localities a small, deciduous tree. Bark light grey to reddish, thin, smooth, exfoliating in narrow longitudinal flakes, light brown inside. Wood very hard, durable, used for building, agricultural implements, carts, boats, shafts, axe-handles, &c. The tree sometimes exhibits twisted fibre from left to right, and often produces burrs, especially when injured. Large trees are often hollow in the centre, and the timber has the fault of splitting a good deal near the centre. Apart from its economic value this tree is important silviculturally as a common companion of the sal, teak, and other valuable species.

DISTRIBUTION AND HABITAT. Sub-Himalayan tract from the Jumna eastwards, ascending to 3,000 ft., Bengal, Assam, Chota Nagpur, central India, and the Indian Peninsula southwards to the Nilgiris, Upper Burma. As a general rule the tree is not gregarious, though often plentiful. In the sub-Himalayan tract it is a common constituent of the sal forests, and is also plentiful on the dry waterless *bhabar* tract, a deep boulder formation along the base of the outer hills. Here the forest is often of a dry mixed type, and in the United Provinces among the chief associate species are *Adina cordifolia*, *Terminalia tomentosa*, *T. belerica*, *Hymenodictyon excelsum*, *Holoptelea integrifolia*, *Acacia Catechu*, and *Phyllanthus Emblica*. Farther east, in the Duars of Bengal and western Assam, it is one of the commonest trees along the base of the outer hills and on the dry boulder formation skirting them, the forest being of a dry character and the chief trees besides *Lagerstroemia* being *Shorea robusta*, *Terminalia Chebula*, *T. belerica*, *Phyllanthus Emblica*, *Sterculia villosa*, *Dillenia pentagyna*, *Bombax malabaricum*, *Gmelina arborea*, *Premna*, *Stereospermum*, and others, and near rivers *Dalbergia Sissoo* and *Acacia Catechu*.



FIG. 223. *Lagerstroemia parviflora*. Seedling $\times \frac{7}{4}$.
 a, seed ; b-e, germination stages ; f, g, development of seedling during first season.

In these forests it attains considerable dimensions ; a girth of 8 ft. 2 in. and a height of 100 ft. were measured in the Borojhar forest, Buxa, and this is by no means a maximum. In the *bhabar* tract of the Duars it sometimes springs up gregariously on gravel and boulder deposits near rivers, after the land has become elevated above river-level ; here pure patches of young *Lagerstroemia*, sometimes of considerable extent, may be found with large specimens of *Dalbergia Sissoo* scattered among them, the latter being the survivors of a former riverain forest (see Fig. 224).

The tree is found in fair quantity throughout the dry mixed forests of the Indian Peninsula as far south as the Nilgiris, in association with teak, *Terminalia tomentosa*, *Anogeissus latifolia*, *Diospyros Melanoxyton*, *Ougeinia dulbergioides*, *Buchanania latifolia*, *Phyllanthus Emblica*, and other species. As a rule it does not attain large dimensions, trees over 6 ft. in girth being rare ; in the Dangs forests of Surat, however, large trees are occasionally met with, a girth of 13 ft. having been recorded. In the Bori forest of the Central Provinces a girth of 15 ft. has been measured.

In Upper Burma it occurs in mixed deciduous forest along with teak, *Terminalia tomentosa*, *Dillenia pentagyna*, *Bursera serrata*, *Anogeissus acuminata*, *Schleichera trijuga*, *Lagerstroemia Flos-Reginae*, and other species.

The tree accommodates itself to a variety of soils and geological formations, including black cotton soil and trap ; it thrives best on deep porous loam, and although it is often found on clay, it does not stand water-logging.

In its natural habitat the absolute maximum shade temperature varies from 100° to 118° F., the absolute minimum from 30° to 50° F., and the normal rainfall from 30 to 180 in.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The leaves turn brown towards the end of the cold season and are shed in February–March, the new leaves appearing in April–May. The panicles of small white fragrant flowers appear from April to June, and the capsules ripen and open from December to February ; they are 3- to 4-valved, 0.7–1 in. or more in length, ovoid or obovoid, brown when ripe, and remain some time on the tree after ripening. The seeds including wing (Fig. 223, *a*) are 0.4–0.6 in. long, brown, with a terminal papery wing, having a thick stiff curved ridge along one edge.

The germinative power of the seed is frequently poor. Tests were carried out at Dehra Dun for three successive years : in the first two years the seed was almost entirely unfertile, but in the third year it germinated well.

GERMINATION (Fig. 223, *b–e*). Epigeous. The radicle emerges from the end of the seed opposite the wing, the hypocotyl arches and extricates the cotyledons in straightening, the seed-coat being left as a rule on or in the ground, though it is sometimes carried up over the cotyledons, falling with their expansion.

THE SEEDLING (Fig. 223).

Roots : primary root long, terete, tapering, wiry : lateral roots moderate in number and length, fibrous. **Hypocotyl** scarcely distinguishable, up to 0.1 in. long. **Cotyledons** : petiole 0.2–0.5 in. long, channelled above, glabrous : lamina 0.4–0.5 in. by 0.4–0.5 in., foliaceous, orbicular, base tapering, entire, green, glabrous. **Stem** erect, quadrangular, often winged, green or reddish, glabrous ; internodes 0.1–0.5 in. long. **Leaves** simple, alternate, or first pair sometimes sub-opposite, sessile, exstipulate, 0.3–2 in. by 0.2–1 in., ovate

acuminate, base acute, entire, glabrous, margins minutely pubescent, venation arcuate, lateral veins 4-10 pairs.

The growth of the seedling is moderately fast. Young plants raised at Dehra Dun reached a height of 4 in. in two months, and 12 in. by the end of the year ; on poor ground the growth is slower. For its best development the young plant requires a porous well-drained soil free from weeds. Young seedlings are very frost-tender, unlike coppice-shoots, which resist frost fairly well. They do not stand heavy shade or suppression from a dense growth of grass.

SILVICULTURAL CHARACTERS. The tree is a light-demander, and soon becomes suppressed under shade. It is fairly frost-hardy. In the abnormal drought of 1907 and 1908 in the forests of Oudh it proved to be decidedly hardy ; saplings, however, were affected in the severe drought of 1899 and 1900 in the Central Provinces. Cattle avoid it, and on heavily grazed areas coppice-shoots often remain untouched after most of the other species have disappeared : sometimes the presence of pure *Lagerstroemia parviflora* may be the result of heavy grazing.

The tree coppices and pollards vigorously. Experiments were carried out in 1909 in North Chanda, Central Provinces, in which trees were coppiced in successive months from April to September ; in no month did a single stool fail to coppice, a result not attained by any other species experimented with. Again, Mr. A. E. Osmaston¹ records complete success in the case of 25 trees coppiced in experiments in the Gorakhpur district, United Provinces. The following numbers of shoots per stool have been measured in the United Provinces :

1. Gorakhpur district : age one to sixteen years ; average 1.6 to 3.2 shoots per stool.
2. Gonda district : age one and two years ; average 1.7 to 2.7 shoots per stool.

NATURAL REPRODUCTION. The natural reproduction of this tree requires further study. As far as is known, fertile seed is not produced in abundance every year, though in certain years reproduction springs up in quantity. Loose porous bare soil appears to favour natural reproduction, which often comes up readily on abandoned cultivation on well-drained ground, and on riverain alluvial gravel which has risen above river-level. Immunity from damage by grazing and good power of recovery from the effects of fire and mutilation are factors which favour the natural reproduction of this species : the admission of light also stimulates it.

SILVICULTURAL TREATMENT. As a rule this tree is treated as an accessory to species of greater value, such as teak or sal, and its treatment is subordinated to that of the principal species. It is eminently adapted for working as coppice, a rotation of thirty years being generally sufficient for the production of poles for building purposes.

RATE OF GROWTH. 1. *High forest.* The following results of girth measurements in sample plots are available :

¹ Ind. Forester, xxxvii (1911), p. 429.



FIG. 224 Former riverain forest of *Dalbergia sissoo* in process of conversion to forest of *Lagerstroemia parviflora*, large tree of former species surrounded by pure sapling growth of latter, Goalpara Assam



FIG 225 *Lagerstroemia lanceolata*, Bombay.

Lagerstroemia parviflora : girth increment in high forest sample plots.

Province.	Forest division.	Locality.	Number of years under measurement.	Number of trees under measurement	Girth classes.	Mean annual girth increment for period.
					ft.	in.
United Provinces	Dehra Dun	Thano and Kansrao	17	3	1-2	0.13
	Saharanpur	Dholkhand		1	2-3	0.30
		Lakarkot	..	5	0-1	0.23
		Malowala		32	1-2	0.23
				4	2-3	0.34
	Lansdowne	Andermajhera	17	12	0-4	0.11
	Haldwani	Kauria	4	3	1½-3	0.14
		Aonla Khera	4	1	0-1½	0.40
		Chilla	11	4	3-6	0.34
		Khonani	6	5	1½-6	0.31
Central Provinces	S. Kheri	Kishanpur	9	2	2-3	0.10
	Balaghat	Raigarh	8	1	1-2	0.09
				1	2-3	0.03

These figures indicate a decidedly slow rate of growth. The sample plots in question, however, are all in sal forest, and presumably many of the *Lagerstroemia* trees are dominated or even suppressed.

The following rate of growth has been deduced from measurements of 41 trees in the Dholkhand, Lakarkot, and Malowala sal sample plots, Saharanpur forest division, United Provinces, and of 22 trees scattered in sal sample plots in the Buxa forest division, Bengal :

Lagerstroemia parviflora : rate of growth in high forest, Saharanpur and Buxa divisions.

Saharanpur.			Buxa.		
Age.	Girth.		Age.	Girth.	
years.	ft. in.		years.	ft. in.	
20	..	0 10	100	1 11	4 1
30	0 7	1 3	110	2 1½	4 6
40	0 9	1 8	120	2 5	4 11
50	0 11½	2 0	130	2 8½	5 4
60	1 2	2 5	140	3 0	5 8
70	1 4½	2 10	150	..	6 1
80	1 6½	3 3	160	..	6 6
90	1 9	3 8			

A cross-section 4 ft. 6 in. in girth in the silvicultural museum, Dehra Dun, had 56 rings, giving a mean annual girth increment of 0.96 in.

2. *Coppice*. The rate of growth of *Lagerstroemia parviflora* coppice is at first usually more rapid than that of sal, but the latter afterwards outgrows the former. The following are some recorded measurements of young coppice-shoots :

Lagerstroemia parviflora : rate of growth of young coppice, compared with sal or teak in the same coupes.

Locality.	Age.	<i>Lagerstroemia parviflora</i> .	Sal.	Teak.
	years.	ft.	ft.	ft.
Gonda, United Provinces	1	6.8	4.7	
	2	10.3	10.0	
	2	9.5	7.6	
Gorakhpur, United Provinces	1	7.8	4.5	
	1	7.3	2.8	
	3	9.1	9.7	
Thano, Dehra Dun, United Provinces	5	15.0 ¹	..	
Bhandara, Central Provinces	1	6.3	..	

¹ Mean girth 6 in.

Mr. A. F. Broun recorded the following measurements made in 1886 in coppice coupes at Bullawala, Dehra Dun :

Lagerstroemia parviflora : rate of growth of coppice, Bullawala, Dehra Dun.

Age. years.	Mean height.		Mean girth.	
	<i>Lagerstroemia parviflora</i> .		<i>Lagerstroemia parviflora</i> .	
	ft.	in.	in.	Sal.
8	19	1.1	6.2	7.1
8	15	4.2	6.4	8.3
10	18	6.0	6.0	5.9

The results of measurements made by Mr. C. M. McCrie in 1910 in coppice coupes in the Gorakhpur district, United Provinces, are shown as follows :

Lagerstroemia parviflora : rate of growth of coppice, Gorakhpur.

Age. years.	Mean height.		Mean girth.	
	<i>Lagerstroemia parviflora</i> .		<i>Lagerstroemia parviflora</i> .	
	ft.	Sal.	in.	Sal.
2	6.8	3.0	—	—
4	9.8	7.0	3.9	2.0
6	12.3	10.3	4.8	2.9
8	14.5	13.0	5.4	3.8
10	16.4	15.3	6.0	4.8
12	18.0	17.5	6.5	5.8
14	19.4	19.2	6.9	6.7
16	20.5	20.9	7.2	7.5

2. *Lagerstroemia Flos-Reginae*, Retz. Syn. *L. speciosa*, Pers. Vern. Jarul, Beng. ; Ajhar, Ass. ; Taman, bondara, Mar. ; Hole-dasal, challa, Kan. ; Pumarathu, Tam. ; Manimarathu, Mal. ; Pyinma, Burm. ; Eikmawè, U. Burm.

A large deciduous tree with a rounded crown and large handsome mauve flowers. Bark smooth, grey or yellowish grey, exfoliating in fairly thin irregular flakes. Wood light red, hard, durable, used for construction, boat-building, canoes, carts, and other purposes. This is one of the most important timber trees of Burma and Assam.

DISTRIBUTION AND HABITAT. Assam, Bengal, Chittagong, western and southern India from North Kanara and the southern Konkan southwards through Malabar to Travancore, Chota Nagpur (not very common, and of small size). Common throughout Burma, but not in the dry zone : (Ceylon, in the moist low country. In the sub-Himalayan tract the tree is not considered to be indigenous west of Bengal, but it is certainly plentiful, though of comparatively small size, along the banks and within some little distance of certain streams in forest lands in the Gorakhpur district, United Provinces, and if not indigenous it has at all events run wild. It is planted for ornament in many parts of India.

The tree is typically found along the banks of rivers and streams and on low-lying swampy ground. It is not, however, always confined to such places, for in Burma it is often scattered in the moister types of lower mixed deciduous forest on alluvial ground and sometimes in evergreen forest : in the upper mixed forests it is usually confined to the banks of streams and to alluvial flats in their neighbourhood. Its growth is best on rich deep alluvial loam : on badly-drained swampy ground it is usually small and crooked.

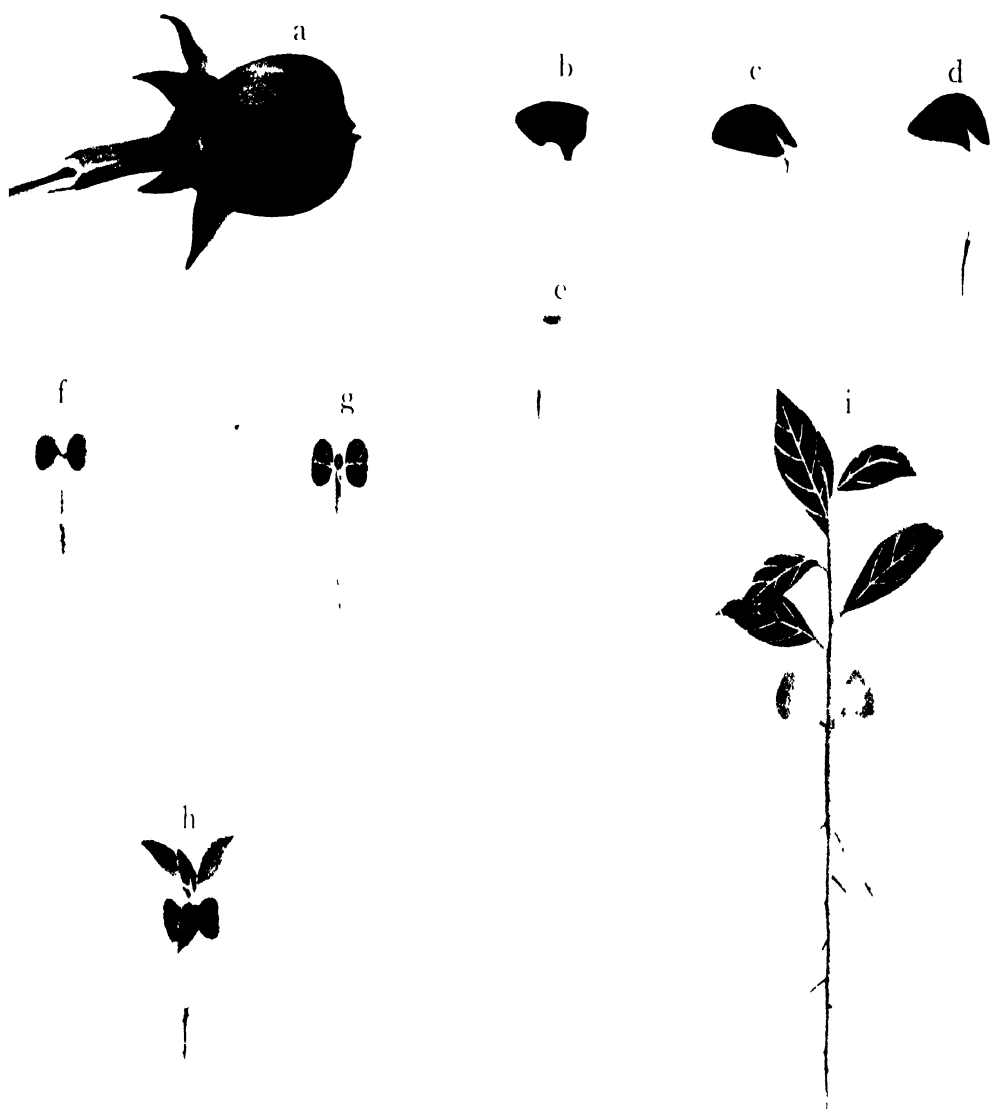


FIG. 226. *Lagerstroemia Flos-Reginae* SEEDLING. }

a—Fruit b —Seed c - f Germination stages g - i—Development of seedling during first season

In its natural habitat the absolute maximum shade temperature varies from 95° to 110° F., the absolute minimum from 36° to 65° F., and the normal rainfall from 60 (about 50 in Gorakhpur) to 180 in. or more.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The tree sheds its leaves about February–March, the leaves turning reddish before falling; the new leaves appear in April–May. The large terminal panicles of mauve flowers, 2–3 in. in diameter, appear from April to June, at which time the trees are extremely handsome. The capsules (Fig. 226, *a*), 5- to 6-valved, broadly ovoid, 0.7–1 in. long, ripen from November to January, according to locality, though they do not actually open and scatter the seeds for some little time (February, Goalpara, Assam, 1915; March–April, Dehra Dun, planted trees). The seeds (Fig. 226, *b*) are light brown, angular, fairly hard, with a stiff brittle wing, the whole 0.6–0.7 in. long; they are often unfertile. The tree seeds at an early age; vigorous plants raised from irrigated broadcast sowings at Dehra Dun commenced to bear seed at the age of three years.

GERMINATION (Fig. 226, *c-f*). Epigeous. The radicle emerges from the end of the seed opposite the wing; the hypocotyl arches slightly and extricates the cotyledons in straightening. The seed-coat is left on or in the ground.

THE SEEDLING (Fig. 226).

Roots: primary root moderately long, wiry, flexuose, thick in vigorous plants; lateral roots numerous, long, fibrous. **Hypocotyl** distinct from root, 0.4–0.7 in. long, quadrangular, reddish or green, glabrous. **Cotyledons:** petiole 0.05 in. long; lamina 1.5–2 in. by 2–2.5 in., foliaceous, somewhat fleshy, orbicular reniform, broader than long, apex truncate or slightly retuse, entire, glabrous. **Stem** erect, 3- to 5-angled and winged, woody, glabrous, young parts green or reddish, older parts greenish brown; internodes 0.1–1.3 in. long. **Leaves** simple, alternate, sessile or sub-sessile, exstipulate, earlier leaves small, the size increasing with successive leaves, 0.5–2.5 in. by 0.3–1.5 in. in natural seedlings, up to 8 by 3 in. in vigorous artificially grown seedlings, elliptical or elliptical lanceolate or obovate, acute or acuminate, base acute, entire or undulate, glabrous, paler beneath than above, venation arched, with a prominent intramarginal vein, midrib often reddish, veins prominent. raised on under side.

During the first season the growth of the seedling is slow, a height of only 2–6 in. being ordinarily attained by the end of the year; subsequently the growth is considerably faster. Weeding and irrigation, particularly the former, greatly stimulate growth. Plants raised from weeded broadcast sowings on tilled ground at Dehra Dun reached in three years a height of 10 ft. when irrigated, and 8 ft. when not irrigated. In the first year they attained a height up to 3 ft. The leaves fall about November to January, and new growth starts in March (Dehra Dun). In their earlier stages the seedlings are small and delicate, and are apt to be washed away by heavy rain; they are sensitive to frost and drought.

SILVICULTURAL CHARACTERS. The tree is a moderate light-demander, soon becoming suppressed under shade which is at all heavy; it is less light-demanding than teak. In its natural habitat it is exposed neither to frost nor ordinarily to drought: in the severe frost of 1905 trees planted at Dehra Dun suffered. It is a decidedly moisture-loving tree. It coppices well, the coppice-shoots growing vigorously.

NATURAL REPRODUCTION. Under natural conditions the seeds lie on the ground during part of the hot season and often become washed into heaps during the early showers. Germination takes place early in the rainy season. The factors influencing natural reproduction require further study, but experiments carried out so far indicate that bare loose soil is favourable, and that weed-growth is most unfavourable. For the establishment of natural reproduction a considerable amount of light is required. The sensitiveness of young seedlings to drought has been alluded to. The prevalence of natural reproduction round the edges of swamps and along the sides of watercourses is probably due mainly to the fact that the seeds are washed together in quantity on the bare ground, and the seedlings develop well under the conditions of light and soil moisture which they enjoy. Good natural reproduction is reported to have appeared in the Yetkanzin forest, Toungoo, Burma, in an area where bamboos had flowered, which had been fire-protected for many years and then burnt after the flowering of the bamboos.¹

ARTIFICIAL REPRODUCTION. Owing to the lightness of the seed and the small size of the young seedlings, direct sowings are less suitable than transplanting from the nursery. Broadcast sowings on cleared and hoed ground at Dehra Dun have, however, proved successful on an experimental scale. A fair amount of planting has been done within recent years in Assam, notably in Lakhimpur. Direct sowings in lines 6 ft. apart were carried out between 1876-7 and 1882-3 in the Nambor forest, Sibsagar, Assam, the *Lagerstroemia* being mixed with *Mesua ferrea*. In 1903 the area was found to be very densely stocked with young poles of both species, in which the *Lagerstroemia* greatly outnumbered the *Mesua*.² Transplanting after pruning the roots has been tried without success in Sibsagar.

Mr. R. Bourne informs me that in Malabar he obtained the best results in germination by sowing the seeds in flat beds divided into squares surrounded by small mud walls, so that when the beds were flooded the water stood in them for some time.

RATE OF GROWTH. There are few reliable statistics showing the rate of growth. The following heights of young plants are recorded in different plantations in the Jokai reserve, Lakhimpur, Assam : ³

Age (exclusive of time in nursery)	Average height. ft.
Year of planting	6
1 year	7
2 years	10
3 years	9

A few trees planted at Kuch Behar in 1873-4 had attained in 1881 a maximum girth of 2 ft. 4 in. with a height of 16 ft. The locality was reported to be unsuitable, the trees having developed a low shrubby growth.⁴

The Rangoon plains forests working plan ⁵ gives an estimate of the rate of growth based on ring-countings, the results being as follows :

¹ Burma Forest Report, 1914-15.

² Working Plan for the Nambor Reserved Forest, Sibsagar, A. R. Dicks, 1905.

³ Forest Report, 1913-14.

⁴ W. R. F. in Ind. Forester, vii (1881-2), p. 41.

⁵ Working Plan for the Plains Forests, Rangoon Division, Burma, J. J. Rorie, 1905.



FIG. 227. *Lagerstroemia tomentosa* SEEDLING $\times 2$

a Fruit b Seed c f Germination stages g, h Development of seedling during first season
i Seedling in second season

Girth.	Corresponding age.
ft. in.	years.
1 6	36
3 0	63
4 6	94
6 0	125

The mean annual girth increment, 0.576 in., is identical with that estimated for teak growing in the same forests.

3. *Lagerstroemia tomentosa*, Presl. Vern. *Lèza*, Burm.

A large deciduous tree, reaching a height of 100 ft. or more, and a girth of 10 to 12 ft. or more in favourable localities. Bole usually straight and clean to a considerable height. Bark about 0.3–0.4 in. thick, light grey, fairly smooth, with longitudinal cracks. Wood light grey to greyish brown, moderately hard, close grained, fairly durable, used for planking, building, canoes, carts, shafts, wheels, and furniture, and deserving of more notice for boxes and such purposes. It has been tested and reported suitable for match manufacture.

DISTRIBUTION AND HABITAT. The tree is common throughout the greater part of Burma, except in the dry zone. It is found in evergreen and semi-evergreen tropical forest, and in mixed deciduous forest of the upper and lower types. In the upper mixed forests it is associated with teak, *Xylia dolabriformis*, and their common companions, usually occupying the lower slopes of hills and well-drained valleys on deep rich soil; in the drier types of mixed forest it is either absent or is found in stunted form. In the lower mixed forests on alluvial ground it is sometimes very plentiful, particularly in some localities along the base of the eastern slopes of the Pegu Yoma.

In its natural habitat the absolute maximum shade temperature varies from 100° to 110° F., the absolute minimum from 40° to 55° F., and the normal rainfall from 40 to 200 in.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The tree is leafless for a time in the hot season. The panicles of handsome white flowers, 1–1.3 in. in diameter, appear in April–May, and the capsules (Fig. 227, *a*) commence to ripen about November, dehiscing at various times up till April; they are ovoid, 0.5–0.6 in. long, dark brown when ripe. The light winged seeds (Fig. 227, *b*) are about 0.3 in. long; they escape from the capsules chiefly during the hot season and are carried by wind to some distance from the tree. Like that of other species of this genus, the fertility of the seed is uncertain. Tests carried out at Dehra Dun showed that the seed retains its vitality to some extent for one year if carefully stored. At Peradeniya, Ceylon, where the tree was introduced in 1891, flowering takes place twice a year, in April and October; this may also be the case sometimes in Burma.

GERMINATION (Fig. 227, *c–f*). Epigeous. The radicle emerges from the end of the seed opposite the wing, the hypocotyl arches somewhat, and the seed-coat is either left in or on the ground or is carried up, falling with the expansion of the cotyledons.

THE SEEDLING (Fig. 227).

Roots: primary root moderately long and thick, terete, tapering, woody; lateral roots numerous, long, fibrous. **Hypocotyl** distinct from root, 0.3–0.5 in. long, quadrangular, glabrous. **Cotyledons**: petiole up to 0.06 in. long; lamina 0.2–0.3 in. by 0.25–0.3 in., foliaceous, sub-orbicular or broadly obovate, apex rounded, truncate or retuse, base tapering, entire, green. **Stem** erect, quad-

angular, stellate tomentose; internodes 0.1–0.6 in. long. *Leaves* simple, exstipulate, first pair opposite, subsequent leaves on main stem alternate, sometimes sub-opposite, those on side branches opposite or sub-opposite. Petiole 0.1 in. long, stellate tomentose. Lamina 0.8–3.2 in. by 0.3–1.3 in., elliptical lanceolate, acuminate, base tapering, entire, stellate pubescent.

During the first season the seedling remains comparatively small, but from the second year onwards the growth is fairly fast. Seedlings raised in a box at Dehra Dun were 1 ft. 6 in. to 2 ft. 7 in. in height by the middle of the second season, and one of these which was transplanted reached a height of 9 ft. 7 in., with a basal girth of $7\frac{1}{2}$ in. by the end of the fourth season. These seedlings for the first two or three years developed long thin weak stems and had the habit of climbers rather than of erect plants; eventually, however, they became rigid and erect. The young seedlings are sensitive to drought; frost is unknown in the natural habitat of the tree, but at Dehra Dun the young seedlings proved to be very sensitive to frost, and all those grown in the open succumbed during the first winter.

NATURAL REPRODUCTION. The seeds fall during the hot season, and are washed into heaps by the early showers. Germination takes place at the beginning of the rainy season. The factors influencing natural reproduction require further study, but experiments at Dehra Dun indicate that bare loose moist soil is favourable to germination, and that stiff soil and weed-growth are unfavourable; also that in early youth shade is beneficial in preventing mortality through drought. These experiments, however, are not conclusive, more especially as climatic conditions at Dehra Dun are very different from those met with in the natural habitat of the tree.

ARTIFICIAL REPRODUCTION. Experiments at Dehra Dun showed that young plants can best be raised on well-drained porous soil kept moist and protected from the sun. Transplanting can be carried out without much difficulty in the second rainy season. No plantations of this species, so far as is known, have ever been made. A young tree in the Forest Research Institute grounds, Dehra Dun, raised from seed sown in 1912, shows good promise.

4. *Lagerstroemia lanceolata*, Wall. Syn. *L. microcarpa*, Wight. Benteak. Vern. *Nana*, Mar.; *Nandi*, *bili-nandi*, Kan.; *Ventek*, Tam. (Fig. 225.)

A large deciduous tree with smooth whitish bark exfoliating in large papery strips. Wood moderately hard, used for building, furniture, boxes, &c. A valuable timber, but liable to split and not durable in the open.

DISTRIBUTION AND HABITAT. This is one of the most important trees of the west coast of the Indian Peninsula, where it is very common along and below the Western Ghats from Bombay southwards to Travancore, ascending the hill ranges of Coorg, Mysore, and Travancore, and the Nilgiris and other hills, to 4,000 ft. In East Khandesh it is rare, and in Kolaba and Surat is only scattered.

In its natural habitat the absolute maximum shade temperature varies from 95° to 115° F., the absolute minimum from 43° to 63° F., and the normal rainfall from 30 to 180 in. or more. It attains its best development in regions of heavy rainfall, for instance in Kanara, Malabar, and Coorg, where it reaches a large size. It grows well both on hill slopes and in valleys, preferring crystalline rocks to laterite. It is found most commonly in mixed deciduous forests associated with teak, *Terminalia tomentosa*, *T. paniculata*, *Xylia xylocarpa*, *Dalbergia latifolia*, *Pterocarpus Marsupium*, *Adina cordifolia*, and other species.

It occurs also in evergreen forest, but usually in the form of large trees surviving from a former deciduous forest into which the evergreen species have encroached.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The tree is leafless for a time in the hot season. The small white flowers appear from April to June, and the fruits ripen in the cold season. The small light seeds fall early in the hot season and germinate at the beginning of the rains : they are carried by the winds to some distance from the tree. Mr. H. Tireman mentions that he has twice tried to raise seedlings in Coorg, but on neither occasion did any seed germinate : this would indicate that the germinative power, like that of other species of this genus, is uncertain.

SILVICULTURE AND NATURAL REPRODUCTION. The factors influencing natural reproduction require further study. So far as is known the seedlings do not stand exposure to a hot sun, and benefit by slight shade, while they require a fair amount of moisture in the soil. Bare loose soil aids natural reproduction, which appears freely on abandoned cultivation. The seedling is capable of bearing considerable shade, but later the tree benefits by an abundance of light, though it is less light-demanding than teak. Fire does not appear to do much harm to reproduction, though it produces hollows at the bases of the trees. In the moister types of forest fire-protection has had an adverse effect in encouraging the growth of dense evergreen vegetation which has prevented the reproduction of this and other light-demanding deciduous trees. Mr. H. Tireman notes that the limited amount of grazing in Coorg is beneficial in keeping down undergrowth and favouring natural reproduction. The tree coppices well.

RATE OF GROWTH. 1. *High forest.* The following table has been compiled from measurements, based on ring-countings, recorded in high forest working plans in the North Kanara district, Bombay :

Lagerstroemia lanceolata : rate of growth in diameter in high forests of the North Kanara district, Bombay.

Age. years.	Supa fuel reserves. ¹ (1906)	Ankola high forest. ² (1908)	Kalinaddi slopes. ³ (1909)	Sopin hosalli high forest. ³ (1910)	Ankola- Kumta coast. ³ (1911)	Sirsi town forests. ³ (1913)	Yekambi Sonda high forest. ³ (1914)
	in.	in.	in.	in.	in.	in.	in.
10	2.2	2.7	2.9	1.8	2.0	1.1	1.3
20	4.4	4.9	5.3	3.6	4.8	2.4	3.2
30	6.7	6.7	7.5	5.3	7.2	3.8	5.5
40	8.9	8.5	9.7	7.1	9.3	5.3	7.8
50	10.8	10.3	11.9	9.0	11.4	6.9	10.0
60	12.2	11.9	14.2	10.9	..	8.2	11.8
70	13.2	13.3	15.9	12.8	..	9.7	13.4
80	13.7	14.8	17.5	14.5	..	11.2	15.0
90	..	16.2	19.0	16.2	..	12.6	16.4
100	..	17.5	20.3	17.8	..	13.8	17.8
110	..	18.6	21.7	19.3	..	15.0	19.1
120	..	19.6	22.9	20.8	..	16.1	20.3
130	..	20.6	23.9	..	..	17.2	21.4
140	..	21.5	25.0	..	..	18.3	22.5
150	..	22.4	25.9	..	..	19.4	23.6
160	..	23.2	26.8	..	..	20.5	24.6
170	..	24.0	27.5	..	..	21.6	25.6
180	..	24.7	28.2	..	..	..	..

Note.—Diameter excludes bark : average bark thickness 0.33 in. in Ankola, 0.3 in. in Kalinaddi slopes and Sopin hosalli.

¹ Measurements by D. A. Thomson.

² Measurements by R. S. Pearson.

³ Measurements by P. E. Aitchison.

Mr. H. Tireman has recorded the following measurements, made in 1916, of trees which sprang up in two teak plantations in Coorg, formed in 1884 and 1891, and therefore 32 and 25 years old respectively :

Plantation of 1884.			Plantation of 1891.		
Height.	Girth at breast height.		Height.	Girth at breast height.	
ft.	ft.	in.	ft.	ft.	in.
(1) 65	2	9	(1) 50	2	5
(2) 61	2	8	(2) 49	2	6
(3) 60	2	8	(3) 48	2	8
(4) 58	1	10	(4) 47	2	7
(5) 51	1	10	(5) 45	2	2
(6) 50	2	10	(6) 45	1	10

Since the age of these trees cannot be greater than that of the plantations, the mean annual girth increments would be at least 0.91 and 1.13 in. in the two plantations respectively.

Measurements in North Malabar gave the following results :

Average age at	6 in. diameter	28 years.
" "	12 "	50 "
" "	18 "	72 "
" "	24 "	103 "

Gamble's specimens gave six to eight rings per inch of radius, representing a mean annual girth increment of 0.78 to 1.05 in.

2. *Coppice*. Mr. H. Murray records the following measurements of coppice-shoots in Belgaum :

Age.	Height.	Diameter.
years.	ft.	m.
5	10.5	2.3
10	19.0	3.6
15	23.0	4.6
20	27.5	5.8
25	31.5	6.9
30	34.5	8.0
35	37.0	9.0
40	39.0	9.75

5. *Lagerstroemia macrocarpa*, Wall. Vern. *Kônpyinma*, Burm.

A moderate-sized tree, somewhat resembling *L. Flos-Reginae*, but with larger leaves and flowers. The latter are 3 in. or more in diameter, and the tree is extremely handsome when in flower in the hot season. This species is most commonly found in the plains forests and on cultivated lands, often in rather low bushy form ; it is usually confined to moist or even swampy situations.

6. *Lagerstroemia hypoleuca*, Kurz. Vern. *Pyinma*, Burm. (in Andamans) ; *Pábdá*, And.

A large deciduous tree with thin whitish bark. Wood hard, durable, used for building, shingles, wheel-work, and other purposes ; apt to split in seasoning. This is one of the principal species of the Andamans, where it occurs chiefly in deciduous forests associated with *Pterocarpus dalbergioides*, *Terminalia bialata*, *T. Manii*, *T. Catappa*, *Odina Wodier*, *Bombax insigne*, *Albizia Lebbek*, *Adenanthera pavonina*, *Sterculia* spp., and others. *Lagerstroemia hypoleuca* is found usually on sandy soil on low ground, and is less common in the hills. It extends into evergreen forest, where it is associated



FIG. 228 *Duabanga sonneratioides* -SEEDLING, $\times \frac{1}{2}$
a Seed $\times 5$ b-d Germination stages (b and c $\times 5$, d $\times 2\frac{1}{2}$) e, f Development of seedling
during first season $\times 1\frac{1}{2}$ g-i Development of seedling during second season $\times \frac{1}{2}$

with various species of *Dipterocarpus* and other trees. Mr. C. G. Rogers¹ notes that the tree seeds freely nearly every year, and the seeds germinate easily; on Wilson Island he mentions that natural reproduction in very open forest is remarkably good, extensive thickets of this species being found. Mr. F. H. Todd² notes that natural reproduction is good in the North Andaman. Flowers June–July; fruits cold season (Kurz).

2. DUABANGA, Ham.

Duabanga sonneratioides, Ham. Vern. *Lampatia*, Nep.; *Khokan*, Ass.; *Myaukngo*, *Mau-lettanshe*, Burm. (Fig. 229.)

A large deciduous tree with characteristic long horizontal branches drooping at the ends, and opposite large sessile leaves. Bark greyish brown, peeling off in thin flakes. Under forest conditions the tree forms a long clean bole. Sometimes it attains a very large girth; Mr. J. W. A. Grieve measured a tree 18 ft. in girth in the Tista valley. Wood grey or yellowish grey, soft, seasoning well without warping or splitting, excellent for tea-boxes, for which it is largely used; also used for canoes, and has been reported on as a good wood for match manufacture. As a fast-growing useful softwood this tree is well worth more attention.

DISTRIBUTION AND HABITAT. Eastern sub-Himalayan tract, ascending to 3,000 ft., Assam, Manipur, Chittagong, Burma, Andamans, and Nicobars. It occurs mainly along the banks of streams and on the sides of moist ravines, springing up on landslips and other places where the soil has been exposed, always on well-drained ground. It is essentially a tree of moist warm climates. In its natural habitat the absolute maximum shade temperature varies from 98° to 110° F., the absolute minimum from 36° to 60° F., and the normal rainfall from 50 to 200 in.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The tree is leafless for a time in the hot season. The clusters of large showy white flowers appear at the ends of the long spreading branches in February–March, weighing them down at the ends. The capsules ripen in the end of April or during May. The seeds (Fig. 228, *a*) are minute, averaging 0.05 in. long, tapering at each end to a point, and very light. Tests at Dehra Dun showed that the seed retains its vitality fairly well for a year. The tree flowers and fruits at an early age (six years in the case of a tree planted at Dehra Dun).

GERMINATION (Fig. 228, *b–d*). Epigeous. The testa splits at one end and the radicle emerges; the hypocotyl elongates, carrying the testa above ground, and the latter falls with the expansion of the cotyledons.

THE SEEDLING (Fig. 228).

Roots: primary root at first minute, resembling a fine thread, with a mass of woolly hairs round upper part; by end of first season from two to several inches long, moderately thick, with long branching fibrous lateral roots, chiefly from upper part of main root. **Hypocotyl** distinct, at first less than 0.1 in. long, very fine, white or green, afterwards elongating to 0.2–0.3 in., becoming thicker, often dark red. **Cotyledons** at first less than 0.05 in. long, after-

¹ Report on the Exploration of the Forests in the South Andaman and other Islands, 1906, para. 23.

² Draft Working Plan for the North Andaman, 1906.

wards enlarging to 0.15–0.2 in. by 0.1 in., ovate, apex rounded, base obtuse or sub-cordate, entire, delicate, green, later often turning dark red. *Stem* erect, quadrangular, the corners winged by the decurrent leaf-bases, glabrous, green with a pink tinge in first season; internodes in first season 0.1–0.5 in. long. *Leaves* simple, alternate on main stem, opposite on side branches, sub-sessile or with petioles up to 0.2 in. long, exstipulate, first two or three leaves often small and abortive. Normal leaves 1–3 in. by 0.3–0.9 in. in first season, up to 8 by 2 in. in second season, oblong lanceolate, acute or acuminate, base elongated and decurrent down petiole and stem, decurrent wings expanding abruptly on joining stem, entire, glabrous, dark green with petiole and decurrent wings often pink.

After germination the young seedlings are extremely minute, almost resembling green powder on the surface of the ground; they are smaller even than those of *Adina cordifolia* or *Stephegyne parvifolia*. The growth during the first season is slow, a height of only 1 or 2 in. being attained by the end of the year. During the second year the growth is more rapid, a height of 2 ft. or more being attained; thereafter the growth is very rapid. Seedlings raised at Dehra Dun proved to be very sensitive to drought and frost; the former is seldom and the latter never experienced within its habitat. The seedlings are somewhat subject to the attacks of insects, and in the forest young plants are readily eaten by deer and cattle. Young saplings develop characteristic long horizontally spreading branches at an early age.

NATURAL REPRODUCTION. Natural seedlings spring up on newly exposed ground such as landslips and river-banks, and appear to require for their development an abundance of light and absence of drip from overhanging trees. Complete drainage and loose but moist soil also appear to be necessary. Natural reproduction comes up readily on banks of silt in the beds of rivers. Mr. Gamble¹ describes the profusion with which natural seedlings come up on the sites of old charcoal kilns in the Darjeeling *tarai*. The nearest seed-bearers were at least half a mile distant, and the seed must have been carried by wind. The sites of these charcoal kilns evidently offered ideal conditions for the germination of the seed and the development of the seedlings, which did not appear elsewhere in the neighbourhood, even on recently hoed ground.

Experiments at Dehra Dun showed that if seed is scattered soon after ripening over fine earth or powdered charcoal in the open it is washed into heaps by the early monsoon showers, and the minute seedlings appear in groups, but are washed away in quantities during the rains. Only where the drainage is perfect and the young plants grow vigorously enough to obtain hold of the ground before being washed away, is it possible for any seedlings to survive the first season. In the case of charcoal-covered ground it is probable that the exceptional vigour induced by the porosity of the germinating bed is the main cause of the survival of the young seedlings.

ARTIFICIAL REPRODUCTION. Direct sowings on bare hoed ground have been carried out frequently in Bengal, and landslips are occasionally sown up with success. On the whole, however, sowings have proved a failure owing chiefly to the liability of the young plants to be washed away during the first season.

¹ Ind. Forester, iv (1878–9), p. 245.



FIG 229 *Duabanga sonneratioides*

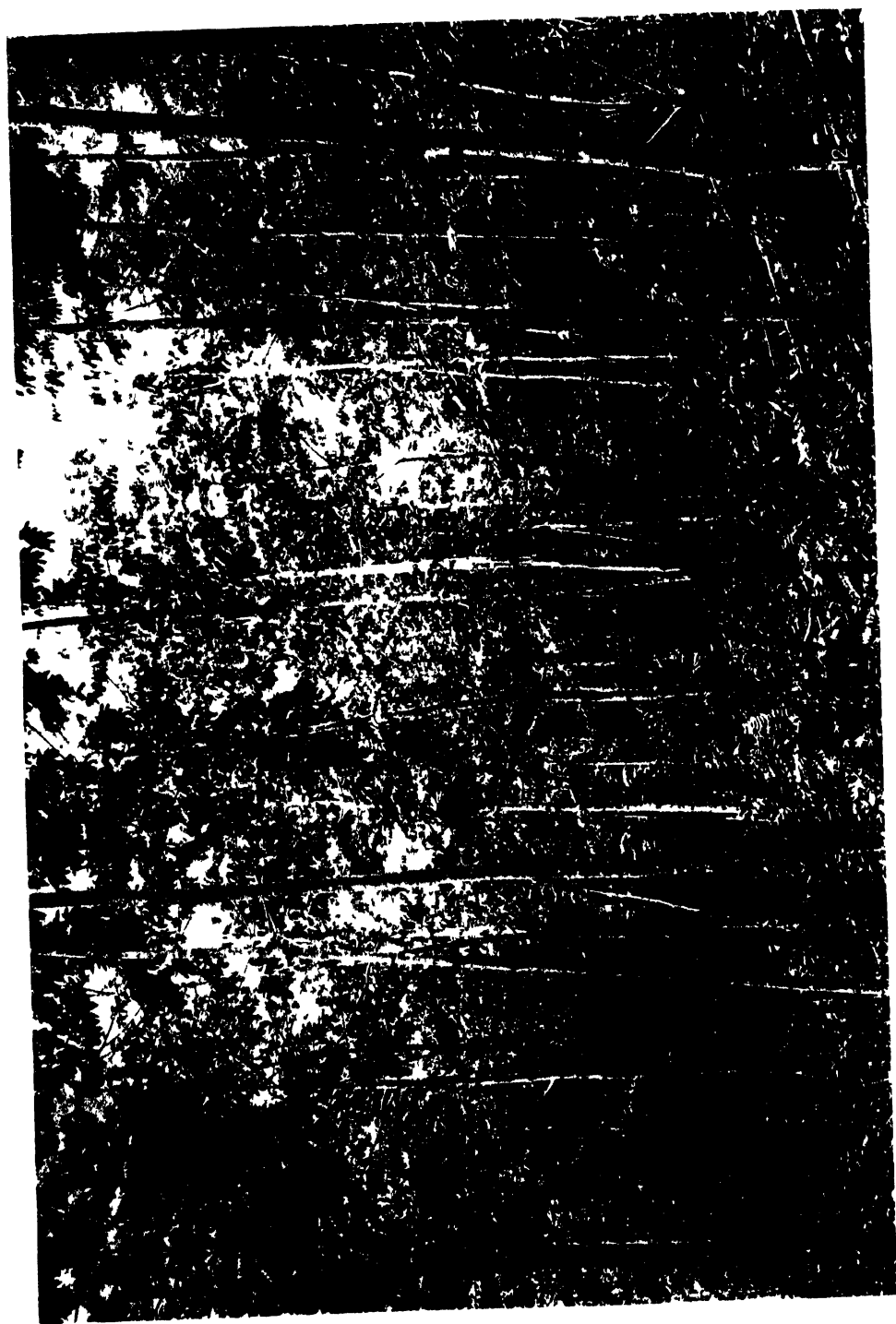


FIG 230 *Duabanga sonneratioides* crop 6 years old, Darjeeling hills

In the Mongpoo plantations of the Cinchona Department, in the Darjeeling hills, the seed is sown about the end of May or beginning of June in well-raised seed-beds of porous soil which have been very little manured, and the beds are sheltered by sloping double bamboo mats about 3 ft. above the ground. The seedlings are pricked out once and are not planted out until early in the rains of the following year, when they are about 1 ft. high.

Experiments at Dehra Dun showed that it is impossible to raise seedlings in open seed-beds, as the minute seedlings are washed away or beaten down and destroyed by heavy rain. The best results were attained by mixing the seeds with fine earth and scattering the mixture on very fine porous soil or on powdered charcoal in May or early June in boxes kept under cover or in well-raised seed-beds protected from rain by screens. Great care is necessary to water the beds or boxes with a very fine spray. The seedlings may be pricked out when about 1-2 in. high, and transplanted at the beginning of the next rainy season. Little difficulty was experienced in transplanting the seedlings provided the roots were kept enclosed in balls of earth. Basket planting would probably prove successful, the seedlings being transferred to baskets towards the end of the first rainy season.

Direct sowings on raised mounds under bamboo mats have given some success in the Tista forest division of Bengal. Mounds of loose soil 3 ft. by 3 ft. at the base and 6 in. high are sown with a pinch of seed and covered with bamboo mats 2 ft. by 2 ft. in size raised 1 ft. above the mounds. The mats are removed as soon as the seedlings are well established, that is, about the end of the rainy season. Superfluous plants are removed and used to fill up gaps.

In plantations protection from deer and cattle is necessary for the first few years.

RATE OF GROWTH. After the first year or two the growth is rapid, an average height increment of 5 ft. a year or more being not unusual. A sapling at Dehra Dun attained a height of 9 ft. 2 in. and a girth of 6½ in. at 4 ft. from ground-level by the end of the fourth season, including a height-growth of only about 1½ in. during the first season; this, in a locality far outside its natural habitat, and subject to more severe cold than it is ordinarily accustomed to, is very fair growth.

Measurements carried out by Mr. E. Marsden in 1917 in three sample plots in the Darjeeling hills gave the following results:

Duabanga sonneratioides: measurements in sample plots,
Darjeeling hills.

After thinning.						Yield from thinning in 1917.				Locality.
Number of stems per acre.	Mean girth.	Mean height.	Volume per acre, solid.			Number of stems per acre.	Volume per acre, solid.			
			Timber over 24 in. girth.	Small-wood.	Total.		Timber over 24 in. girth.	Small-wood.	Total.	
			ft. in.	ft.	cub. ft.		cub. ft.	cub. ft.	cub. ft.	
328	0 11·6	34	—	310	310	317	—	123	123	Below Lopchu.
131	2 2·0	50	364	559	923	86	---	316	316	Near Birick.
110	3 3·7	78	2,308	408	2,716	99	—	575	575	Sumbong.

The second of these plots is shown in Fig. 230. These figures show a very rapid rate of growth and a high yield. Trees measured in 1915 in a plantation in the Jalpaiguri district had attained a height of 18 ft. in five years.

The rate of growth as deduced from measurements in two unthinned sample plots in the Darjeeling division was as follows :¹

Duabanga sonneratioides : girth increment in unthinned sample plots,
Darjeeling division.

Age. years.	Mean girth. ft. in.	Age. years.	Mean girth. ft. in.
10	1 10 $\frac{1}{4}$	40	5 2 $\frac{3}{4}$
20	3 2	50	6 4
30	4 2 $\frac{1}{2}$	60	7 4 $\frac{1}{2}$

The growth here is considerably slower than that shown in the first statement : this is possibly due to the fact that no thinnings were carried out.

Ring-countings in respect of 25 trees in the Tista valley gave an average of 3.1 rings per inch of radius, representing a mean annual girth increment of 2.026 in.²

Gamble's specimens averaged 5 rings per inch of radius (mean annual girth increment 1.26 in.), while one specimen showed 2 rings per inch (mean annual girth increment 3.14 in.).

3. SONNERATIA, Linn. f.

This genus comprises trees with opposite entire thick leaves, growing in the mangrove swamps of littoral regions (see under 'Rhizophoraceae'). There are four Indian species, of which two, *S. acida*, Linn. f., and *S. apetala*, Ham., are fairly widely distributed along the coasts and two, *S. alba*, Smith, and *S. Griffithii*, Kurz, are far more local.

Species 1. *S. apetala*, Ham.; 2. *S. acida*, Linn. f.; 3. *S. Griffithii*, Kurz; 4. *S. alba*, Smith.

1. *Sonneratia apetala*, Ham. Vern. *Keora*, Beng.; *Kandal*, Mar.; *Kylanki*, Tel.; *Marama*, Tam.; *Kambala*, Burm.

A small to moderate-sized evergreen tree with slender drooping branches and light glaucous-green foliage. Bark black, smooth, with horizontal oval lenticels. The tree produces thin upright rather sharp pneumatophores from its superficial roots. It coppices vigorously. Wood moderately hard, used for planking, furniture, knees of boats, and fuel.

DISTRIBUTION AND HABITAT. Tidal forests of the coasts of India and Burma. This is one of the chief constituents of the mangrove formation, growing gregariously and springing up in more or less pure patches, usually on new alluvial land thrown up in the form of islands or of flats in the bends of tidal rivers and estuaries. It is a common tree in the Sundarbans, appearing on newly formed land and gradually dying out on the higher ground, where it tends to be replaced by *Heritiera Fomes* and other species.

FLOWERING AND FRUITING. The whitish flowers appear from April to June. Ripe fruits have been received from the Sundarbans in September.

¹ Statistics compiled in the Silviculturist's Office, 1916-17, Ind. For. Rec., vol. vi, pt. v.

² Working Plan for the Darjeeling Forests, J. W. A. Grieve, 1912.

They are globose, about 0·7–0·8 in. in diameter, fleshy, indehiscent, containing several angular irregularly-shaped seeds about 0·3 in. long, with a rather hard testa. The fruits are buoyant, and are distributed by water; they are also said to be eaten by birds. After falling they soon rot and disintegrate, the seed being scattered.

GERMINATION. Epigeous. The testa splits at one end and the radicle emerges. The hypocotyl arches and the testa is carried above ground, falling with the expansion of the cotyledons.

RATE OF GROWTH. Mr. Trafford¹ notes that this tree grows more rapidly than any other in the Sundarbans; he estimates the mean annual girth increment at 1·2 in.

2. *Sonneratia acida*, Linn. f. Vern. *Ora*, *orcha*, Beng.; *Tiwar*, Mar.; *Thirala*, Mal.; *Tabu*, *tamu*, Burm.

A small evergreen tree with dull green foliage and black shining lenticellate bark. It produces pneumatophores in the shape of asparagus-like rootlets emerging from the mud. This is another common species of the mangrove swamps, with an even wider distribution than *S. apetala*.

3. *Sonneratia Griffithii*, Kurz.

A species of the Burma coast, strongly resembling *S. acida*.

4. *Sonneratia alba*, Smith.

A shrub or small tree of the mangrove swamps of the Andamans, Mergui, and the Konkan (Brandis).

4. WOODFORDIA, Salisb.

Woodfordia floribunda, Salisb. Vern. *Dhau*, *dhaw*, *dāwi*, Hind.; *Dhaiti*, Mar.; *Jaji*, Tel.; *Yetkyi*, *pattagyè*, *panlè*, Burm.

A large shrub with more or less fluted stem and long spreading branches, widely distributed throughout India and the drier parts of Burma, ascending to 5,000 ft. in the Himalaya; also in Africa, Arabia, China and elsewhere, and in Ceylon (rare).

This is a common gregarious shrub which springs up on landslips, abandoned cultivation, and other open places, killing out grass and acting as a useful soil-improver and a most efficient nurse to tree species, including sal, which come up freely under its protective cover. For clothing landslips it is invaluable. It is not eaten by cattle, and is frost-hardy, and thus appears often in extensive pure masses on open ground subject to grazing. In tracts where shifting cultivation has been practised the presence of old bushes of *Woodfordia* gradually dying out under the shade of poles of tree species usually indicates the site of a former cultivated clearing in which the shrub has appeared and the tree species have grown up through it, eventually suppressing it.

The bright red flowers, which appear from January to April in axillary cymes along the spreading branches, make the plant a conspicuous sight. The capsules ripen from April to June and shed the minute seeds, which require open well-drained ground for germination. Mr. Haines notes that it scatters its seeds slowly for several weeks, and only that seed germinates

¹ Working Plan for the Sundarbans, 1912.

and survives which is lucky enough to fall just before a several days' period of continuous wet weather.¹

The most successful way in which to grow the plant artificially is to sow the seeds in broken bricks ; on ordinary seed-beds it is very difficult to obtain germination and to raise seedlings. The plant coppices well ; coppice-shoots five years old in the Gorakhpur district, United Provinces, averaged 10 ft. 3 in. in height.

5. PUNICA, Linn.

Punica Granatum, Linn. Pomegranate. Vern. *Anar*, Hind. ; *Dharu*, *daruna*, Pb.

A deciduous shrub or small tree, indigenous in Persia and Afghanistan ; wild and probably indigenous in Hazara, where it is very common and often gregarious on dry rocky ground on the limestone of the outer hill ranges at 3,000–5,000 ft., often associated with *Olea cuspidata* ; also found in the Kagan valley up to 6,000 ft. on dry hill-sides. It is widely cultivated for the sake of its fruit, and is frequently found as an escape from cultivation, particularly in the Himalaya, where it ascends to 7,000 ft. and where it sometimes forms dense crops on the gravel and boulder deposits in the beds of dry ravines and similar places. It is cultivated from seed or from cuttings. In the Himalaya it flowers chiefly from April to July, and the fruits ripen from July to October.

ORDER XXX. SAMYDACEAE

Genera 1. *CASEARIA*, Jacq. ; 2. *HOMALIUM*, Jacq.

1. CASEARIA, Jacq.

Species 1. *C. tomentosa*, Roxb. ; 2. *C. glomerata*, Roxb.

1. *Casearia tomentosa*, Roxb. Vern. *Chilla*, *bheri*, Hind. ; *Modi*, Mar.

A small deciduous tree with spreading branches, tomentose leaves, and small greenish flowers clustered in the axils of the leaves. The wood is of little use, but the tree is common in the sub-Himalayan tract and the Indian Peninsula in deciduous forests, open scrub jungles, and waste lands. It often owes its abundance to its immunity from damage by grazing. It is very drought-hardy, as was shown in the abnormal drought of 1907 and 1908 in Oudh. It suffered much in the severe frost of 1905 in northern India, but apparently has good powers of recovery, since it is frequent in grassy blanks subject to annual frosts. The tree coppices well. The rate of growth in high forest is slow, sample plots in sal forest in the United Provinces showing mean annual girth increments of 0.09, 0.19, 0.22, and 0.34 in. Coppice-shoots grow more rapidly. Measurements made in 1911 in a coppice coupe one year old in the Tikri forest, Gonda, United Provinces, showed an average height of 4.5 ft. as against 4.7 ft. for sal. Measurements made in 1910 by Mr. McCrie in coppice coupes in Gorakhpur, United Provinces, showed the following results for *Casearia tomentosa* and sal respectively :

¹ Inspection note, Palamau, 1915.

Casearia tomentosa : coppice measurements, Gorakhpur, United Provinces.

Age. years.	Mean girth.		Mean height.	
	<i>Casearia</i> . in.	Sal. in.	<i>Casearia</i> . ft.	Sal. ft.
2	—	—	3.5	3.0
4	1.7	2.0	6.0	7.0
6	2.4	2.9	8.0	10.3
8	3.0	3.8	9.5	13.0
10	3.5	4.8	11.0	15.3
12	4.0	5.8	12.5	17.5
14	4.5	6.7	14.0	19.2
16	5.0	7.5	15.0	20.9

The following measurements were recorded in 1886 by Mr. A. F. Broun in coppice coupes at Bullawala, Dehra Dun :

Casearia tomentosa : coppice measurements, Bullawala, Dehra Dun.

Age. years.	Mean girth.		Mean height.	
	<i>Casearia</i> . in.	Sal. in.	<i>Casearia</i> . ft.	Sal. ft.
8	5.2	8.3	12.5	6.2
8	6.0	..	22.0	..
9	7.2	8.6	15.0	16.0
10	7.6	5.9	14.0	11.9

2. *Casearia glomerata*, Roxb. Syn. *C. graveolens*, Dalz. Vern. *Chilla*, nara, Hind. ; *Giridi*, Uriya ; *Bokhada*, Mar. ; *Barkholi*, Nep.

A small to moderate-sized deciduous tree, sometimes a mere shrub, with long spreading branches and leaves which turn a deep coppery red in the cold season. Brandis unites *C. glomerata*, Roxb., and *C. graveolens*, Dalz. Gamble (*Man. Ind. Timbers*) describes the former as a large evergreen tree of the eastern Himalaya, Khasi hills, Sylhet, and hills of Upper Burma. Manson,¹ describing the eastern Himalayan tree, notes that it is often found in second growth forest, perhaps most commonly on warm sunny aspects ; seedlings are plentiful and do well with plenty of light while thriving also under cover, and the tree is a capital nurse for restocking blanks.

The tree is common in mixed forests throughout the greater part of India and in Burma, where it is frequent in the lower mixed forests. The wood is little used.

2. HOMALIUM, Jacq.

Homalium tomentosum, Benth. Vern. *Myaukchaw*, Burm.

A large deciduous tree with thin very smooth whitish bark, found in deciduous forests throughout Burma except in the drier parts of the dry zone. Also in Chittagong and the Northern Circars (Gamble). This is one of the most characteristic trees of the mixed deciduous forests of Burma, its smooth clean white bole rendering it very conspicuous. It attains large dimensions, Fig. 231 shows a tree 12 ft. in girth and 120 ft. in height. It is abundant in the upper mixed forests with teak, *Xylia dolabriformis*, and their associates (see Fig. 232). It is also common in the better drained portions of the lower mixed forests, but not in areas which are water-logged for part of the year. Generally speaking, its presence appears to be an indication of good drainage.

¹ Working Plan for the Darjeeling Forests, 1893.

It seeds freely, and natural seedlings often spring up in great abundance, standing moderate shade and often forming dense pure thickets : in some of the teak plantations of Burma natural reproduction springs up freely and forms a lower story to the teak. The factors influencing natural reproduction have not been studied in detail. Seedlings raised at Dehra Dun succumbed to frost, which, however, is not met with in their natural habitat. The tree coppices well ; an average of 3 shoots per stool was recorded in coppice measurements in the Rangoon plains forests. The wood is tough and elastic, but is apt to develop small cracks in seasoning. It is an excellent fuel. The rings are distinct on a smooth cross-section. A specimen from Burma showed 9 rings per inch of radius, giving a mean annual girth increment of 0·7 in.

ORDER XXXI. DATISCACEAE

TETrameLES, R. Br.

Tetrameles nudiflora, R. Br. Vern. *Jermala*, *bondale*, Kan. ; *Ugad*, Mar. ; *Chini*, Tam., Mal. ; *Thitpók*, Burm. ; *Baing*, U. Burm.

A lofty deciduous tree with a long clean bole and immense plank buttresses at the base. Bark greyish white, fairly smooth. This tree is a conspicuous one in moist tropical and evergreen forests in the eastern sub-Himalayan tract and outer hills, Western Ghats and Nilgiris, and in Burma, towering above the evergreen vegetation. Gamble records a tree measured by him in the Buxa forests, Bengal, 154 ft. high and 15 ft. in girth. It sheds its leaves about January, and the new leaves do not appear until late in the hot season or early in the rains. The yellowish green flowers, which appear in February–March when the tree is leafless, are much sought after by bees, which often build their hives in this tree : the capsules ripen in April–May, and the small seeds are carried to a distance by the wind. The rate of growth is rapid, but no detailed records are available. The wood is whitish, soft, rather coarse, and not durable ; in southern India it is used for dug-out canoes, after treatment with fish oil to increase its durability : it is also used for rough packing-cases

ORDER XXXII. CACTACEAE

OPUNTIA, Mill. Prickly pear.

The name ‘prickly pear’ has been given to certain species of *Opuntia* introduced from South America. The commonest species naturalized in India is *O. Dillenii*, Haw., with flat succulent jointed branches, long sharp spines, and tufts of bristles ; the flowers are bright yellow tinged with red. A red-flowered species common in the neighbourhood of Madras is said to be *O. spinosissima*, Mill.

Prickly pear was introduced into India, it is believed, less than a century ago, but it has spread with such rapidity in the drier parts of the country, particularly in the Deccan and southern India, that it is now one of the most noxious weeds with which the forest officer has to contend. Provided it is kept in check it is an extremely good hedge plant, pieces of the stem and branches stuck in the ground quickly taking root, spreading and forming an



FIG 231 *Homalium tomentosum*, girth 12 ft height 120 ft , Minhla reserve,
Tharrawaddy, Burma , the bamboo is *Bambusa polymorpha*



FIG. 232. *Homalium tomentosum* (two white smooth-barked trees, the right-hand one forked) in upper mixed forest, Prome, Burma.

impenetrable and formidable hedge. The fruits are eaten by man, animals, and birds, and the seeds are spread by their agency. The plant thrives on dry barren ground and is amply protected by its spines, and thus it spreads unchecked over waste and forest lands even where there is heavy grazing. To some extent it serves a useful purpose in grazed areas, in affording protection to seedlings of forest trees, which are able to establish themselves amid the clumps of prickly pear. But any good effect the plant may have in this respect is far outweighed by the harm it does in monopolizing large areas to the exclusion of forest growth and fodder grass.

Various efforts have been made to eradicate prickly pear over given areas, particularly in Madras, but the process has proved a costly one. Mere cutting or uprooting is of little avail, since the cut pieces, if left on the ground, merely take root and produce new masses of prickly pear. Burying the cut pieces in deep pits has been tried, but even with a covering of earth 1 ft. thick new plants made their way up and the surface of each pit became a dense mass of prickly pear. Stacking the cut pieces on a layer of brushwood and burning them proved more successful, the stacks being left to dry for a few months and then burnt: a few young plants subsequently came up, but they were dug up without difficulty. Mr. A. Lodge has tried poisoning the prickly pear by cutting it into pieces and watering them with a weak solution of arseniate of soda; the results were quite successful, the pieces turning black and shrivelling up, but the operation was expensive, and the use of a deadly poison necessitated careful supervision.

It is doubtful if the eradication of prickly pear over extensive areas will be feasible unless some means can be discovered of recouping the cost by providing for its remunerative utilization. When deprived of its spines it is utilizable as fodder for cattle, though the latter appear to take to it only by degrees. An interesting experiment in burning off the spines and feeding cattle with chopped-up pieces of prickly pear, to which 6 per cent. by weight of cotton seed was added, is described by Messrs. E. W. Horn and S. G. Mutkekar in the *Agricultural Journal of India*, vol. ix, pt. ii (April 1914), p. 190. The experiment in question proved decidedly successful, the animals gaining appreciably in weight and condition. A method of burning off the spines with vaporized petrol is described in the *Indian Forester*, vol. xlii (1916), p. 379 (quoting from the *Pioneer*). Other possible uses for the prickly pear which have been suggested are the manufacture of alcohol or of paper pulp.

ORDER XXXIII. RUBIACEAE

A large and important order, furnishing not only useful timber trees but also trees and shrubs yielding drugs, dyes, and edible products, e. g. *Cinchona*, *Coffea*, *Morinda*, and *Rubia*. Most of the important timber trees (*Anthocephalus*, *Adina*, *Nauclea*, and *Stephegyne*) are characterized by very small light seeds which for successful germination require bare ground devoid of weed-growth, while the minute seedlings are liable to perish in quantity through being washed away by rain; their reproduction is therefore dependent on somewhat special conditions.

Genera 1. *ANTHOCEPHALUS*, A. Rich.; 2. *ADINA*, Salisb.; 3. *STEPHEGYNE*,

Korth. ; 4. NAUCLEA, Linn. ; 5. HYMENODICTYON, Wall. ; 6. WENDLANDIA, Bartl. ; 7. GARDENIA, Linn. ; 8. RANDIA, Linn.

1. ANTHOCEPHALUS, A. Rich.

Anthocephalus Cadamba, Miq. Syn. *A. indicus*, A. Rich. ; *Nauclea Cadamba*, Roxb. ; *Sarcocephalus Cadamba*, Kurz. Vern. *Kadam*, Hind. ; *Roghū*, Ass. ; *Kadwal*, Kan. ; *Kadambe*, Tel. ; *Vellei kadambu*, Tam. ; *Mau*, Burm.

A large deciduous (or sometimes evergreen ?) tree with spreading branches and rather large shining leaves with prominent veins ; the leaves are much larger in young saplings and coppice-shoots than in older trees. Bark grey, smooth in young trees, becoming darker and longitudinally fissured in older trees, exfoliating in small rectangular plates, yellowish brown inside. Wood yellowish white, soft, an excellent tea-box wood, and also used for planking, dug-out canoes, &c. ; has been highly recommended for match manufacture. This tree deserves more attention as a useful fast-growing soft-wooded species.

DISTRIBUTION AND HABITAT. The sub-Himalayan tract from Nepal eastwards, Bengal, Assam, Chota Nagpur (valleys in Singhbhum, Haines), Burma, Northern Circars, and the west coast from North Kanara southwards to Travancore, but Talbot does not consider it indigenous in the Bombay Presidency ; also in Ceylon. It is cultivated in many parts of India. It is a tree of moist warm regions, frequenting moist types of deciduous and evergreen forests, and often occurring on alluvial ground along rivers and also on swampy ground. It prefers deep well-drained moist alluvium ; on stiff badly-drained ground the growth is poor. In its natural habitat the absolute maximum shade temperature varies from 96° to 110° F., the absolute minimum from 38° to 60° F., and the normal rainfall from 60 to 200 in. or more.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The leaves fall in the hot season, the tree becoming leafless or nearly so. The small orange-coloured flowers, in globose heads 1·5 to 2 in. in diameter, appear chiefly from May to July. The fruits ripen and fall in January–February (Bengal Duars) ; the pseudocarp is a globose orange fleshy mass of closely packed capsules each containing a number of minute seeds (Fig. 233, *a*), the whole 1·5–2·5 in. in diameter. The fruits are eaten by man and also by cattle, fruit-bats, and other animals, and by birds, the seeds being distributed by their agency. The tree flowers and fruits at an early age (five years in the case of a tree at Dehra Dun).

GERMINATION (Fig. 233, *b–e*). Epigeous. The radicle emerges and the hypocotyl elongates, carrying above ground the cotyledons enclosed in the testa, which usually remains adhering to one cotyledon for some time before falling to the ground.

THE SEEDLING (Fig. 233). .

Roots : primary root at first thin, later becoming long and thick, terete, tapering ; lateral roots numerous, long, distributed down main root but chiefly in its upper part. *Hypocotyl* distinct from root, 0·1–0·3 in. long, terete or slightly compressed, glabrous in young stages. *Cotyledons* sessile, under 0·05 in. long, ovate, acute, entire. *Stem* erect, slightly compressed, sometimes grooved, finely tomentose ; internodes 0·3–1·2 in. long. *Leaves* simple, opposite,

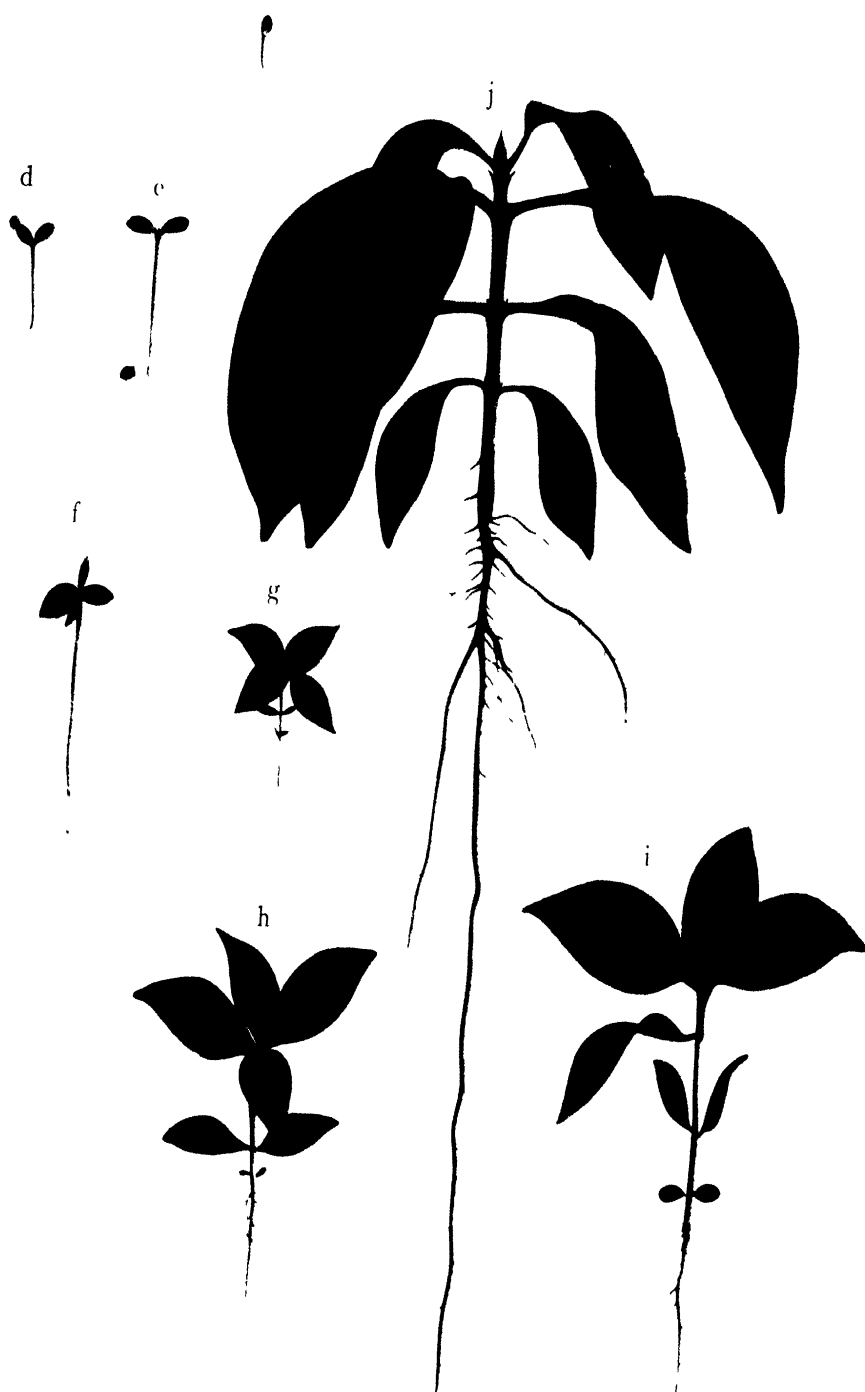


FIG. 233. *Anthocephalus Cadamba*—SEEDLING
 a—Seed $\times \frac{1}{2}$ b-e Germination stages $\times \frac{1}{2}$ f-j —Development of seedling to end of first season (f $\times \frac{1}{2}$, g-j $\times \frac{1}{4}$)

first one or two pairs often abnormally small, 0.1-0.4 in. long. Stipules 0.1-0.4 in. long, triangular, acuminate, fimbriate, pubescent, enclosing the terminal bud. Petiole 0.3-0.8 in. long, flattened above, pubescent. Lamina 1-4.5 in. by 0.4-2.5 in., elliptical ovate or obovate, apex acute or acuminate, base tapering, entire, glabrous or glabrescent above, pubescent beneath; venation arcuate, lateral veins 5-8 pairs, veins of younger leaves often pink.

The young seedlings for the first few weeks after germination are minute, and growth during the first season is comparatively slow, a height of 2-6 in. being ordinarily attained by the end of the season. From the second season onwards, however, the growth is very rapid. Seedlings raised at Dehra Dun reached a height of 6-8 ft. by the end of the second season, and under climatic conditions more suited to this species the growth is faster.

In their younger stages the seedlings are very sensitive to drought and are also liable to damp off with an excess of moisture in the soil. They are very sensitive to frost, which, however, is unknown in the natural habitat of the tree. Seedlings are much subject to damage by insects, especially during the first few weeks.

SILVICULTURAL CHARACTERS. Although young plants will stand a little shade, and require protection from the heat of the sun in their earlier stages, the tree may be regarded as a light-demander; saplings grown under shade become spindly in their efforts to reach the light. The tree coppices vigorously. It is sensitive to frost, which, however, does not occur in its natural habitat. Young saplings are very subject to damage from browsing by cattle and deer, and in grazed areas are prevented from making headway.

NATURAL REPRODUCTION. As already noted, the fruits are readily eaten by cattle and other animals and by birds, and the seeds are spread by their agency. Fruits which fall to the ground and remain uneaten soon disintegrate or are partly consumed by white ants, and with the early showers preceding the monsoon the seeds are washed into heaps along with silt, germinating often in dense masses at the commencement of the rainy season: large numbers of the small seedlings are washed away and destroyed, and it is only where they obtain a secure lodgement until the end of the first rainy season that they have a chance of surviving. Cattle are rather important agents in securing natural reproduction. Seedlings often come up in considerable quantities in grazed areas or in places where cattle are herded together: the young plants are browsed down regularly, but if cattle are kept out for a time the saplings shoot up and establish themselves. In the Bengal Duars excellent natural reproduction may be found coming up in areas previously grazed, but recently closed to grazing (see Fig. 234). In the same locality saplings may often be found springing up in grazed areas under the protection of thickets of *Zizyphus Jujuba*, *Acacia Catechu*, and other thorny species. Reproduction also has a tendency to spring up on newly exposed ground, for example on the sides of new road embankments. Natural seedlings sometimes appear in great abundance; thus Mr. S. E. Peal, quoted by Gamble, says he once estimated that he weeded out 450,000 seedlings on 25 acres of clearance.

ARTIFICIAL REPRODUCTION. The artificial raising of this species from seed is not difficult, but requires great care owing to the small size of the seeds and the seedlings and their liability to be washed away, and to the sensitiveness of the seedlings to drought on the one hand and excessive moisture on the

other. Direct sowings cannot be relied on. Young plants can be raised successfully by broadcasting on well-pulverized fine earth either in well-raised nursery-beds or in boxes; it is necessary that the beds or boxes should be sheltered from the sun and rain, watering being carried out with a very fine spray frequently but sparingly. Sowing may be done from March to May, and the plants should be pricked out in beds during the first season, when about 2 in. high. The larger plants may be transplanted during the first rainy season, but the remainder should be kept for a year in the beds and transplanted early in the following rainy season.

RATE OF GROWTH. During its earlier years the growth is very rapid. Trees planted in 1911 in an avenue at Rajabhatkhawa in the Buxa Duars reached a girth of over 2 ft. and a height of 30 ft. in four years. Mr. S. E. Peal¹ says that the growth is remarkably rapid for the first six or eight years, averaging 10 ft. in height per annum; the growth becomes slower up to twenty years and then becomes very slow. He records measurements of trees sixteen years old which had reached a girth of 5 ft. 5 in. at 6 ft. and 3 ft. 8 in. at 30 ft. from ground-level; for tea-box planking he considers it most profitable to fell at twelve years of age. Sir George Hart notes a case of rapid growth on a low-lying alluvial flat along the Saing river in Toungoo, Burma. Here an attempt was made to establish a teak plantation in 1895. The teak failed, but *Anihocephalus Cadamba* came in naturally. In January 1918, when they could not have been more than twenty-two years old, some of the trees were measured and found to have girths of 7 ft. 6 in., 6 ft. 5 in., 5 ft. 7 in. (twice), and 5 ft. 6½ in.; the height was estimated to be not less than 100 ft., and was probably more nearly 120 ft.

2. ADINA, Salisb.

Adina cordifolia, Hook. f. Syn. *Nauclea cordifolia*, Willd. Vern. *Haldu*, Hind.; *Heddi*, Mar.; *Yettagal*, Kan.; *Manja kadambu*, Tam. and Mal.; *Hnaw*, Burm.

A large deciduous tree with a large crown and cordate leaves. Under forest conditions the tree produces a long straight clean bole, but it is often buttressed and fluted at the base, the buttresses sometimes being of irregular and fantastic shapes. In more isolated positions it produces a thick bole and massive branches with a large spreading crown (see Fig. 236). Bark grey, exfoliating in patches which leave indentations, pinkish inside. Wood yellow, moderately hard, even grained, used for building, furniture, turnery, bobbins, boxes, &c. The tree attains large dimensions. Mr. A. Rodger records one 17 ft. in girth in the Paungadaw reserve, Ruby Mines district, Upper Burma. Mr. H. R. Blanford in 1917 took measurements of a *Ficus*-bound tree felled in the Katha district, Upper Burma. The tree was hollow, and the breast-height girth over the *Ficus* was 24 ft. 5 in. Other dimensions recorded were: (1) total height 138 ft.; (2) length of bole 61 ft.; (3) height to first branch 48 ft.; (4) girth at height of 32 ft. from ground 14 ft. 2 in., and at height of 56 ft. from ground 13 ft. 2 in.

DISTRIBUTION AND HABITAT. *Adina cordifolia* is found scattered in deciduous forests throughout the greater part of India and Burma; also in

¹ Ind. Forester, x (1884), p. 245 (quoting from Ind. Tea Gazette.).

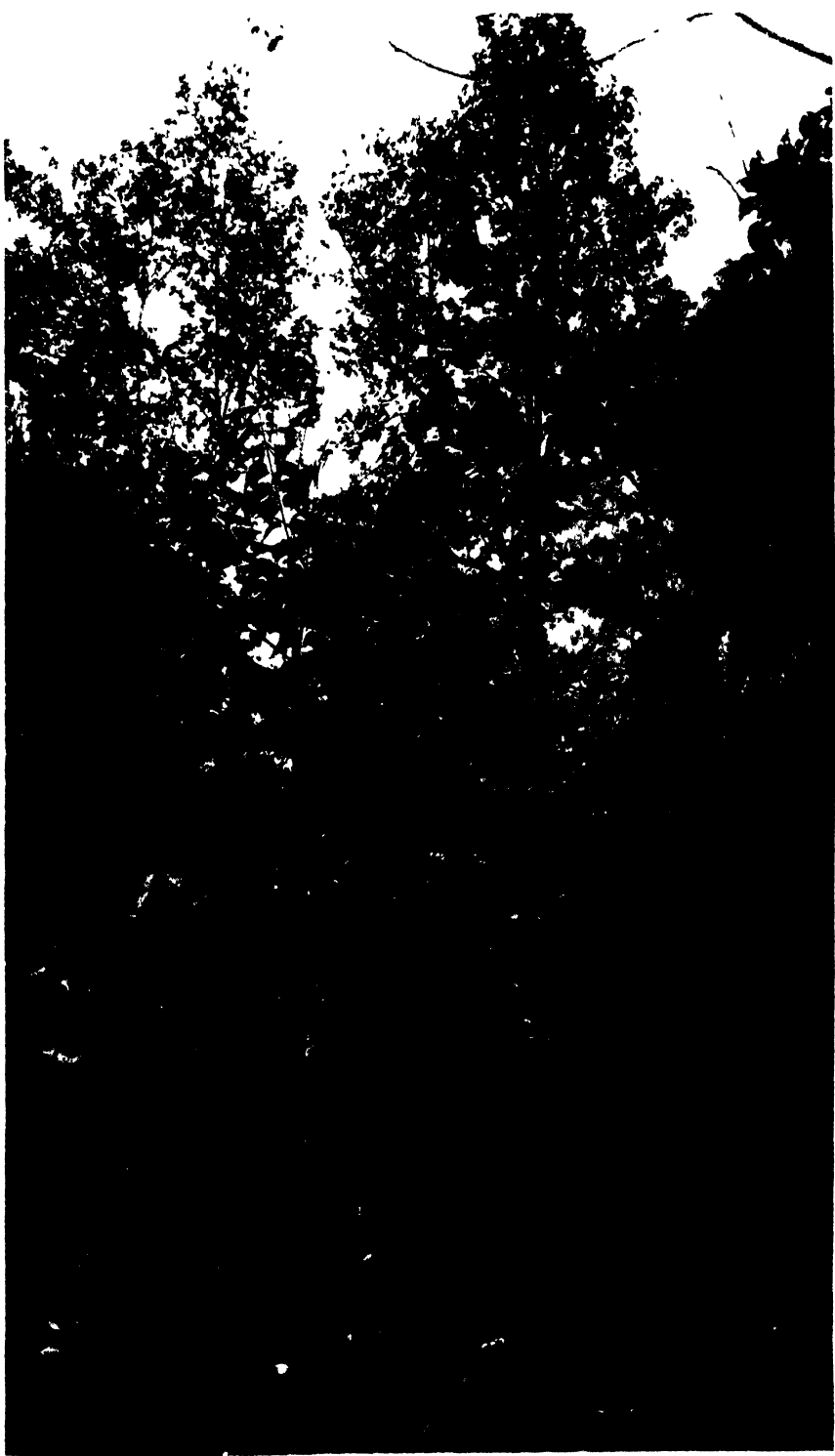


FIG. 234. *Anthocephalus cadamba*, natural reproduction on an area formerly grazed but free from grazing in recent years, Buxa division, Bengal.



FIG 235 *Adina cordifolia* vigorous seedling in third season, taproot broken.



FIG. 236 *Adina cordifolia*, Siwalik hills, United Provinces

the dry regions of Ceylon. In the sub-Himalayan tract large trees are found along the lower slopes of the outer hills from the Jumna eastwards and on the boulder terraces at the base of these hills, where it is sometimes almost gregarious. It is also a familiar tree in the sal forests of the United Provinces. It is fairly common in mixed deciduous and sal forests in Chota Nagpur, and is scattered throughout the greater part of the Central Provinces and the Indian Peninsula generally. In Burma it is found both in the upper mixed and in the lower mixed deciduous forests.

The tree is found most frequently, and attains its best development, on well-drained ground, for instance along the lower slopes of hills among boulders; it also grows well on alluvial ground provided the drainage is good. Like *Stephegyne parvifolia* it is sometimes met with in the sub-Himalayan tract round the edges of swampy depressions where the soil is stiff and the drainage deficient, but in such places it is always stunted and tends to become stag-headed early.

In its natural habitat the absolute maximum shade temperature varies from 100° to 118° F., the absolute minimum from 30° to 55° F., and the normal rainfall from 35 to 150 in.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The leaves are shed about February and the trees remain leafless until about May–June, when the new foliage appears. The large whitish stipules enclosing the leaf-buds are conspicuous; they fall to the ground when the young leaves appear. The yellow globose flower-heads, about 0.6–1 in. in diameter, appear from June to August. By October the globose fruit-heads are almost fully formed, but are still green and unripe; they do not actually ripen and shed their seeds until from April to June of the following year (northern India). The fruit-head (Fig. 237, *a*) consists of a large number of small two-valved many-seeded capsules. After the capsule-valves and seeds have been shed the remains of the fruit-heads appear like small prickly balls formed of the bristle-like axes of the capsules; these, on their peduncles 1–3 in. long, soon fall to the ground and may be found there in quantity during the rainy season. Sometimes the ripe fruit-head falls before shedding the seeds, which may even germinate within the fallen fruit-head (Fig. 237, *b*).

The seeds (Fig. 237, *c*) are very small and light, 0.06 to 0.12 in. long, brown, with numerous minute longitudinal wrinkles, one end tapering to a point, the other terminating in a pair of pointed appendages. As many as 11,000 seeds weigh 1 gramme, giving over 300,000 to the ounce avoirdupois. Tests carried out at Dehra Dun showed that the seed, if carefully stored, retains its vitality well for at least a year.

GERMINATION (Fig. 237, *d–g*). Epigeous. The minute radicle emerges from the blunt end of the seed, the hypocotyl elongates, arching slightly, and the testa, enclosing the cotyledons, is carried above ground, falling with their expansion.

THE SEEDLING (Fig. 237).

Roots: primary root in first season very fine, white, delicate, with a dense mass of woolly hairs in the upper part which soon disappears; in the second season much thickened, tough, terete, tapering, yellowish brown: lateral roots moderate in number and length, fibrous, distributed down main root,

chief lateral roots thickening considerably in second season. *Hypocotyl* distinct from root, 0.1–0.15 in. long, very fine and delicate, white turning green. *Cotyledons* sub-sessile or very shortly petiolate, up to 0.1 in. long, ovate, acute, base truncate or sub-cordate, entire, foliaceous, delicate, green, glabrous. *Stem* erect, terete or compressed, delicate at first, becoming woody later, tomentose; internodes at first 0.1–0.2 in. long, in second season up to 1 in. long. *Leaves* simple, opposite decussate. Leaves of the first season usually only two pairs: petiole up to 0.05 in. long, lamina 0.1–0.5 in. by 0.08–0.4 in., ovate, acute or obtuse, base obtuse, entire, usually reddish, glabrous, or minutely pubescent beneath. Leaves of second season: stipules 0.2–0.5 in. long, ovate, obovate or elliptical, pale green, terminal pair enclosing terminal bud: petiole up to 0.5 in. long, flattened above, tomentose: lamina up to 3.5 by 2 in., elliptical ovate, acute, base acute or obtuse, more rarely cordate, entire, glabrous above, paler and minutely pubescent beneath, lateral veins 6–9 pairs.

For some little time after germination the seedlings are extremely minute and delicate, and are very liable to be washed away or beaten down by the rain. During the first season their development is slow, many attaining a height of only 1 in. or less, with two or three pairs of leaves, though under favourable conditions the more vigorous individuals may attain a height of 4–6 in. or even more, with seven or eight pairs of leaves. During the second season the growth is more rapid, a height of 1–2 ft. or even more being attained under favourable conditions, though on stiff soil or weed-covered ground the growth is poor; good drainage and a free porous soil are essential conditions for successful development. The taproot remains thin, but attains a fair length, during the first season; during the second season, however, it thickens considerably, attaining in some cases a diameter of as much as $\frac{1}{2}$ in. The seedlings are very sensitive to frost and drought. The leaves turn reddish-brown in the cold season and fall about November to February, the new leaves appearing about March or later (northern India). Fig. 235 shows a vigorous seedling in the third season.

In the forest the seedlings require some practice to recognize, even when two or three years old. Superficially they are not unlike those of *Clerodendron infortunatum*, a plant often occurring in the sal forests where *Adina* is found. The *Adina* seedlings, however, can always be distinguished by the terminal stipules enclosing the bud, which are often reddish; also their leaves are entire and glabrous, while those of *Clerodendron* seedlings are serrate and pubescent.

SILVICULTURAL CHARACTERS. Although seedlings spring up under moderate shade, and require protection from drought, from the sapling stage onwards the tree is a strong light-demander. Saplings are sensitive to the rubbing of their leading shoots by overhead trees, and their leaders tend to die where this takes place. The soil requirements of the tree have already been alluded to: good drainage is essential for the best development, trees on stiff soil remaining stunted. Although the seedlings are sensitive to drought the tree is moderately hardy; it was only slightly affected in the abnormal droughts of 1899 and 1900 in the Indian Peninsula and 1907 and 1908 in Oudh. After the seedling stage it is moderately frost-hardy, having suffered only to a slight extent in the severe frost of 1905 in northern India. Young plants and coppice-shoots suffer more than those of almost any other species from browsing by cattle, goats, deer, and *nilgai*; they have good power of recovery,



FIG. 237. *Adina cordifolia* - SEEDLING.

a - Fruit head $\times \frac{1}{2}$ b - Fruit head with germinating seedlings $\times \frac{1}{2}$ c - Seed $\times 2$ d - g - Germination stages $\times 2$ h, i - Development of seedling to end of first season $\times \frac{1}{2}$ j - Development of seedling to end of second season $\times \frac{1}{2}$ (Seedling raised artificially, and more vigorous than a natural seedling)

but remain in a bushy condition with repeated browsing. In some localities bison and sambhar do much damage by barking saplings. The tree coppices readily up to a moderate size, producing numbers of shoots, chiefly from the base of the stool.

NATURAL REPRODUCTION. The minute seeds, shed during the hot season, are often carried to a distance by the wind ; in some cases the fruit-heads fall before all the seed is shed, and the seed may germinate within the fruit-heads. Germination takes place early in the rainy season. The seeds are produced in vast numbers, but the proportion of seedlings which survive and establish themselves is relatively very small. The chief reasons for this are : first, that the minute seeds and young seedlings are very liable to be washed away and so perish ; and second, that the seedlings in their early stage are very delicate. It is often recorded that the natural reproduction of this species is almost entirely absent ; this is, however, far from being the case, and such statements are probably as a rule the result of failure to recognize the seedlings.

For successful germination under natural conditions bare ground appears to be essential, whereas for the successful establishment of the young seedling it is necessary that the seeds, or perhaps even the young seedlings, should be washed up out of the reach of floods during the first rainy season, and find a lodgement in a well-drained situation where the seedlings are not liable to be inundated or washed away. Seedlings have actually been observed in greater or less abundance in the following situations : (1) on small landslips on hill slopes : young plants of all ages are often found on such ground at the base of the outer Himalaya ; (2) in loose earth and débris at the base of the hills ; where this material is washed out over natural well-drained terraces seedlings are often plentiful, and this no doubt explains the origin of the many large old trees found on the boulder terraces at the foot of the Himalaya ; (3) on well-drained alluvial ground near rivers, and on flat ground generally, always provided the ground is bare and not covered with weeds when the seed germinates ; on such ground seedlings may often be found in plenty on small natural humps or mounds, or round the bases of trees or termite heaps, where the seeds or young seedlings have been stranded during the rains ; as many as eight small seedlings were counted in the slightly raised earth round the base of one sal tree on flat ground in the Gorakhpur forests, United Provinces ; (4) on abandoned cultivation, for instance in *taungya* clearings in Burma, where natural reproduction often springs up in quantity ; (5) on the sides of walls, embankments, and ditches ; on the side of the boundary trench round the Birpur forest rest-house, Gonda, United Provinces, were observed numerous saplings sprung from seed washed on to the sides of the trench, probably on new ground when the trench was made ; (6) round the edges of natural tanks and depressions where water lodges during the rains, the seeds being washed up out of the reach of floods and stranded ; (7) on the sites of old charcoal kilns ; seedlings often appear on these owing to the good drainage afforded ; (8) occasionally in the form of epiphytes in forks of or hollows in trees ; (9) in clefts in rocks ; a seedling 1½ ft. high and probably a few years old was found growing tightly wedged in a crack in a large sandstone boulder where there was no soil.

As regards light requirements, the young seedlings probably benefit from shade, provided this does not take the form of low weed-growth, since they are undoubtedly sensitive to drought. That they establish themselves well under moderate shade is certain from the fact that they may be found coming up in sal forest : numerous seedlings were observed thriving on bare alluvial ground under a well-thinned sissoo plantation in the Gorakhpur district, United Provinces, while in the same district seedlings, probably two or three years old, were found in plenty on bare ground under a light cover of *Flemingia Chappar*. That the admission of light greatly stimulates the establishment of natural reproduction is clear from the fact that in various parts of the sal forests of Oudh, where the canopy has been heavily opened out owing to the death of large numbers of trees during the abnormal drought of 1907 and 1908, *Adina* saplings have appeared in quantity because of the admission of light : no doubt many of these plants were present before the canopy was opened, but their growth since then has been greatly stimulated. A dense sal crop in the Gonda district was experimentally opened out in January 1911 in the form of a regeneration felling for the sal ; the plot was inspected two years later, and found to contain numerous young *Adina* seedlings which had made their appearance owing to the admission of light.

Protection from grazing is essential for the successful establishment of natural production, owing to the readiness with which animals browse down the young plants.

ARTIFICIAL REPRODUCTION. As far as is known success has never been attained by means of direct sowings. Experiments at Dehra Dun, by which seed was sown broadcast on hoed ground, as well as on ridges and in trenches, failed entirely, any seed which did germinate being washed away before the seedlings could gain a footing. In the United Provinces broadcast sowings on hoed ground have been tried from time to time, but failure has always been recorded.

Experiments at Dehra Dun have shown that seedlings can be grown successfully in well-raised beds of fine sifted soil with a considerable proportion of sand, or better still on powdered charcoal, but it is essential that the beds should be covered with screens raised about a foot above them, in order to keep off rain and sun, and that watering should be done with a very fine spray. Seed-boxes, however, have proved more successful than seed-beds, and considering the large number of seedlings obtainable from one box there is little question that raising in boxes is to be recommended in preference to any other method. The following procedure has given good results :

The seed-box is filled to within about 1 in. from the top with finely sifted earth with a large proportion of sand, the surface is made smooth and watered, and the seeds are sown about April or May on the wet surface and very lightly covered with fine earth or sand. The box should be kept under cover, and watering with a very fine spray should be done frequently but sparingly. Germination ordinarily takes place in about three to six weeks. As soon as the seedlings are large enough to handle, that is, in about two to three months, they should be pricked out about 2 in. apart in boxes ; the more vigorous ones may even be pricked out about 4 in. apart in nursery-beds. The seedlings will be ready to plant out in the forest early the following rains. Transplanting



FIG. 238 *Stephegyne parvifolia*, height 78 ft , girth 27 ft 6 in , Siwalik hills, United Provinces.

is not unattended with risk owing to the liability of the seedlings to die of drought; care is therefore necessary to keep a ball of earth round the roots. Risk is further avoided by pricking out the plants into baskets or bamboo tubes instead of into boxes or nursery-beds, so that there is no interference with the roots during transplanting. After transplanting it is advisable to keep the soil round the plants well loosened and free from weeds in order to stimulate vigorous growth and to prevent caking of the ground.

RATE OF GROWTH. The following results of girth measurements in high forest sample plots are available :

Adina cordifolia : girth increment in high forest sample plots.

Province.	Forest division.	Locality.	Number of years under measurement.	Number of trees under measurement.	Girth classes.	Mean annual girth increment for period.
					ft.	in.
United Provinces	Saharanpur	Dholkhand	7	1	3-4	1.0
	Lansdowne	Giwain	4	1	1½-3	0.97
			12	3	1½-3	0.27
	Gonda	Chandanpur	2	4	1½-3	0.51
	S. Kheri	Bhira	11	1	1-2	0.72
Central Provinces	Balaghat	Raigarh and Baihar	8	1	2-3	0.53
				1	4-5	0.19

Coppice measurements by Mr. C. M. McCrie in 1910 in the Gorakhpur district, United Provinces, showed an average height and girth of 18.7 ft. and 6.9 in. respectively in seven years, as compared with an average height and girth of 10.2 ft. and 3.87 in. respectively for sal in the same coupe.

Measurements of coppice-shoots on somewhat poor stony ground in the Saitba block, Kolhan forest division, Chota Nagpur, gave the following results :

Adina cordifolia : coppice measurements, Saitba block, Kolhan.

Age.	Mean girth.	Mean height.	Age.	Mean girth.	Mean height.
years.	in.	ft.	years.	in.	ft.
2	—	3.0	10	5.5	13.5
4	3.0	6.5	12	6.1	15.0
6	4.0	9.0	14	6.6	16.5
8	4.8	11.5			

3. STEPHEGYNE, Korth.

Species 1. *S. parvifolia*, Korth. ; 2. *S. diversifolia*, Hook. f.

1. *Stephegyne parvifolia*, Korth. Syn. *Nauclea parvifolia*, Willd. ; *Mitragyna parvifolia*, Korth. Vern. *Kaem, phaldu*, Hind. ; *Kalamb*, Mar. ; *Kadawar, yetega*, Kan. ; *Chinna kadambu*, Tam. ; *Rattaganapa*, Tel. ; *Tein, teinthè*, Burm.

A large deciduous tree with a full rounded crown and a bole often short, fluted, and buttressed. Bark up to 0.8 in. thick, grey, smooth, exfoliating in scales which leave shallow depressions. Wood light pinkish brown, even grained, used for building, furniture, agricultural implements, bobbins, combs, cups, spoons, and other carved and turned articles ; it is less in demand than that of *Adina cordifolia*. Under favourable conditions the tree reaches large dimensions : Fig. 238 shows a tree on alluvial ground in the Siwalik hills 27 ft. 6 in. in girth and 78 ft. high.

DISTRIBUTION AND HABITAT. Throughout the greater part of India and Burma, ascending to 4,000 ft. in the outer Himalaya ; also in Ceylon. Not

reported from north and east Bengal or Assam. Within its habitat the tree is scattered in deciduous forests, not as a rule in any great abundance. Like *Adina cordifolia*, with which it is often associated, it reaches its best development on well-drained ground with deep soil. It is, however, more tolerant of stiff badly-drained ground than *Adina*, and often grows more or less gregariously on low-lying ground with clayey soil, for example on badly-drained savannah lands in Burma, and in many localities round the edges of tanks and swamps; in the *tarai* and plains of the sub-Himalayan tract it occurs frequently in low-lying somewhat swampy ground along with *Eugenia Jambolana*. In such places, however, its development suffers, and as a rule it remains stunted. In the Indian Peninsula it is often found on black cotton soil, and on alluvial ground near rivers.

In its natural habitat the absolute maximum shade temperature varies from 100° to 118° F., the absolute minimum from 30° to 55° F., and the normal rainfall from 35 to 130 in.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The leaves are shed about February–March, and the tree is leafless in April–May, the new leaves appearing about May (northern India). The fragrant globose white or pale yellow flower-heads, 0.7–1 in. in diameter, appear from May to July, and the fruit-heads become full formed, but are still green and unripe, by October; in northern India they do not ripen and shed their seeds until about April–May. Haines mentions that ripe seed has also been collected in November in Chota Nagpur. The fruit-heads (Fig. 239, *a*) are globose, 0.5–0.7 in. in diameter, with numerous small two-valved many-seeded capsules. Sometimes the ripe fruit-heads fall before shedding the seeds, which may even be found germinating within the fallen fruit-heads (Fig. 239, *b*). The seeds (Fig. 239, *c*) are minute, 0.1–0.15 in. long, pointed at either end, light brown, very light, as many as 10,000 weighing 1 gramme, giving nearly 300,000 to the ounce avoirdupois.

GERMINATION (Fig. 239, *d f*). Epigeous. The testa splits at one end and the minute radicle emerges, the hypocotyl elongates, arching slightly at first, and the testa, enclosing the cotyledons, is carried above ground, falling with their expansion.

THE SEEDLING (Fig. 239).

Roots: primary root in first season very fine, white and delicate, with a dense mass of woolly hairs in the upper part which soon disappears; in second season much thickened, terete, tapering; lateral roots moderate in number and length, fibrous, distributed down main root. **Hypocotyl** distinct from root, 0.1–0.15 in. long, very fine and delicate, white turning green. **Cotyledons** very shortly petiolate, up to 0.1 in. long, ovate, acute or rounded, base rounded, truncate or sub-cordate, entire, foliaceous, glabrous. **Stem** erect, delicate at first, becoming woody later; internodes in first season very short, in second season up to 1 in. long. **Leaves** simple, opposite decussate. **Leaves** of first season usually only two pairs, sub-sessile or very shortly petiolate, 0.1–0.5 in. by 0.08–0.4 in., ovate, acute or rounded, base obtuse or acute, entire, often reddish.

Like those of *Adina cordifolia*, which they strongly resemble, the seedlings for some little time after germinating are extremely minute and delicate, and are very liable to be beaten down or washed away by rain. During the first season their growth is very slow, a height of barely $\frac{1}{2}$ in. being ordinarily

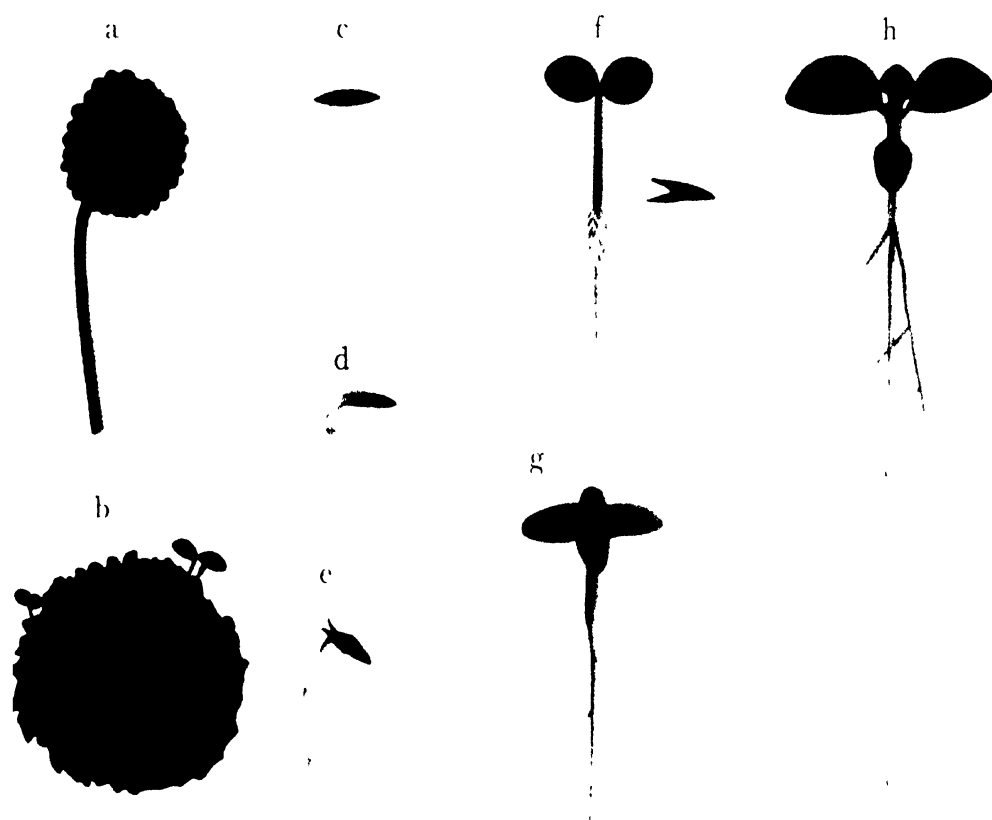


FIG. 239. *Stephogyne parvifolia* - SEEDLING.

Fruit-head $\times 1$ b—Old fruit-head with seedlings germinating $\times 2$ c—Seed $\times 5$ d-f—Germination stages $\times 5$
g-h—Development of seedling to end of first season $\times 3$

attained by the end of the season, and usually about two pairs of foliage leaves being produced.

SILVICULTURAL CHARACTERS. In early youth the tree stands a certain amount of shade, seedlings and saplings being often found under cover, but later it is a light-demander : as in the case of *Adina cordifolia*, saplings are sensitive to the rubbing of their leading shoots by overhead trees. As already mentioned, the tree is capable of growing on badly-drained ground, but its growth suffers in such places. It is fairly hardy against drought, having suffered only to a slight extent in the abnormal droughts of 1907 and 1908 in Oudh, and 1899 and 1900 in the Indian Peninsula. The tree coppices well up to a moderate size. In some localities bison are apt to damage poles of this species by stripping the bark off them.

NATURAL REPRODUCTION. So far as the natural reproduction of this tree has been studied, the conditions influencing it appear to be very similar to if not identical with those affecting the reproduction of *Adina cordifolia*. As in the case of the latter species, the minute seeds are scattered in the hot season, some remaining in the fruit-heads and germinating in them after they fall to the ground, and reproduction springs up in places similar to those in which *Adina cordifolia* reproduction appears, seedlings of the two species being often found together. The survival of reproduction on badly-drained ground is, however, more marked than in the case of *Adina*. Natural reproduction sometimes comes up fairly freely on abandoned cultivation.

ARTIFICIAL REPRODUCTION. According to experiments carried out at Dehra Dun, the most satisfactory method of raising this tree artificially is in boxes, the procedure followed being exactly the same as that described for *Adina cordifolia* (p. 620).

RATE OF GROWTH. The following results are available of high forest sample plot measurements in the Singhbhum forest division, Chota Nagpur :

Stephegyne parvifolia : girth increments in high forest sample plots,
Singhbhum.

Locality.	Number of years under measurement.	Number of trees under measurement.	Girth classes.	Mean annual girth increment for period.
			ft.	in.
Tirilposi block	18	{ 1	5-6	0.58
		{ 2	6-7	0.54
Samta-Hendakuli old road	10	{ 1	6-7	0.37
		{ 2	7-8	0.25

A cross-section 3 ft. 10 in. in girth in the silvicultural museum at Dehra Dun showed 61 rings, representing a mean annual girth increment of 0.75 in. Gamble's specimens showed 5 to 15, averaging 9, rings per inch of radius, representing mean annual girth increments of 0.42 to 1.26, averaging 0.7 in., which is moderate.

Coppice measurements made in 1910 by Mr. C. M. McCrie in the Gorakhpur district, United Provinces, gave the following results for *Stephegyne* as compared with sal :

Stephegyne parvifolia : coppice measurements, Gorakhpur.

Age. years.	Mean girth.		Mean height.	
	<i>Stephegyne</i> . in.	Sal. in.	<i>Stephegyne</i> . ft.	Sal. ft.
2	—	—	4.5	3.0
4	2.2	2.0	9.0	7.0
6	3.3	2.9	12.0	10.3
8	4.2	3.8	14.0	13.0
10	5.0	4.8	16.0	15.3
12	5.8	5.8	18.0	17.5

2. *Stephegyne diversifolia*, Hook. f. Syn. *Nauclea rotundifolia*, Roxb. Vern. *Binga*, Burm. ; *Hnawthein*, U. Burm.

A moderate-sized to large deciduous tree with large nearly orbicular leaves, found in Burma, the Andamans, and Chittagong ; also in Java and the Philippines. The tree is a very common one in the mixed deciduous forests of Burma, both of the upper and of the lower type. In the lower mixed forests on flat alluvial land it is often found in great abundance. Thus in the Thindawyo reserve in the Tharrawaddy district enumerations showed it to be the commonest species in the forest, an average of 118 trees 3 ft. in girth and over being counted per 100 acres.¹ The seeds are minute, like those of *S. parvifolia* and *Adina cordifolia*, and a further study of the tree will no doubt reveal points of similarity to those two species in matters relating to reproduction. Natural reproduction is often abundant on alluvial ground along rivers and streams. The Burma Forest Report for 1914-15 mentions that natural seedlings appeared freely in the Yetkanzin reserve, Toungoo, in an area where bamboos had flowered and which had been fire-protected for many years and burnt when the bamboos flowered ; the reproduction was the result of the burning, which would indicate that clear ground, as in the case of *S. parvifolia* and *Adina cordifolia*, is a favourable factor. It often comes up in abundance on abandoned cultivation. Mr. A. Rodger² in 1916 enumerated a dense pole crop on an old *taungya* cultivated about seventeen years previously in the Prome district of Burma. The enumeration showed 1,150 stems per acre, of which 72 per cent. consisted of *Stephegyne diversifolia*.

4. NAUCLEA, Linn.

Nauclea sessilifolia, Roxb. Syn. *Adina sessilifolia*, Hook. f. Vern. *Teinkala*, Burm.

A large deciduous tree of Cachar, Chittagong, and Burma, occurring in mixed deciduous forests. In Burma it is particularly common in some of the lower mixed forests on flat alluvial ground. Enumerations in the Thindawyo reserve of the Tharrawaddy district showed that after *Stephegyne diversifolia* it was more plentiful than any other species enumerated, showing an average of 98 trees 3 ft. in girth and over per 100 acres.¹ On flat alluvial ground by rivers and streams natural reproduction often springs up in great quantity,

¹ Working Plan for the Satpók, Sitkwin, and Thindawyo Reserves, Tharrawaddy, Burma, 1906.

² Ind. Forester, xlii (1916), p. 499.

forming dense pure patches. The seeds are minute like those of *Adina cordifolia* and *Stephegyne diversifolia*, and a further study of this tree will probably reveal points of resemblance to those species, particularly as regards reproduction. The wood is used for planking and building.

5. HYMENODICTYON, Wall.

Hymenodictyon excelsum, Wall. Syn. *H. thyrsiflorum*, Wall. ; *H. utile*, Wight ; *Cinchona excelsa*, Roxb. Vern. *Kukurkat*, *bhauan*, *bauranga*, Hind. ; *Bhorsal*, Mar. ; *Pottaka*, Tel. ; *Kusan*, Burm.

A large deciduous tree, usually with a straight cylindrical bole and a rounded crown. Bark greyish brown, thick, soft, corky and furrowed on stems of older trees, smooth on poles and branches. Wood white when fresh, turning darker, soft, light, used for planking, boxes, scabbards, toys, &c. ; has been reported as excellent for match manufacture. In northern India, however, the trees have often been noticed to be riddled with large burrows, probably those of a longicorn beetle, and the quality of the wood suffers in consequence.

DISTRIBUTION AND HABITAT. Scattered throughout the greater part of India and Burma in dry mixed deciduous forests. The tree is particularly common on loose dry deposits of boulders and débris along the base of the outer hills in the sub-Himalayan tract. It is one of the characteristic trees of the *bhabar* tract of the United Provinces, a deep boulder formation on gently sloping ground where the subsoil water-level is at a great depth ; here among its commoner companions are *Holoptelea integrifolia*, *Lagerstroemia parvifolia*, *Acacia Catechu*, *Bombax malabaricum*, *Terminalia belerica*, *Adina cordifolia*, *Anogeissus latifolia*, *Cassia Fistula*, and *Odina Wodier*. It is also frequently met with on sandy or stony soils on alluvial ground near rivers, and in savannah lands. It is not infrequent in the sal forests of northern India.

In its natural habitat the absolute maximum shade temperature varies from 98° to 118° F., the absolute minimum from 30° to 60° F., and the normal rainfall from 35 to 90 in.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The large broadly elliptical long-stalked leaves turn a rich yellow and fall in November–December at a time when few other trees are shedding their leaves. The new leaves do not appear until about May, and throughout the intervening months the leafless trees are conspicuous with their candelabra-like fruit-panicles subtended by pairs of dry leafy reddish brown bracts. The small white fragrant flowers, in large terminal panicles, appear from June to August. The capsules are conspicuous from November–December onwards, but do not open and shed their seeds until April–May : they are two-valved, ellipsoidal, 0.5–0.7 in. long, and contain many seeds.

The seeds (Fig. 240, *a*) are flat, winged all round the margin, 0.3 by 0.1 in. including the wing ; they are very light, about 4,800 weighing 1 oz., and are disseminated to a distance by the hot weather winds. Tests carried out at Dehra Dun showed that the fertility of fresh seed is high, but that the seed loses its vitality within a year.

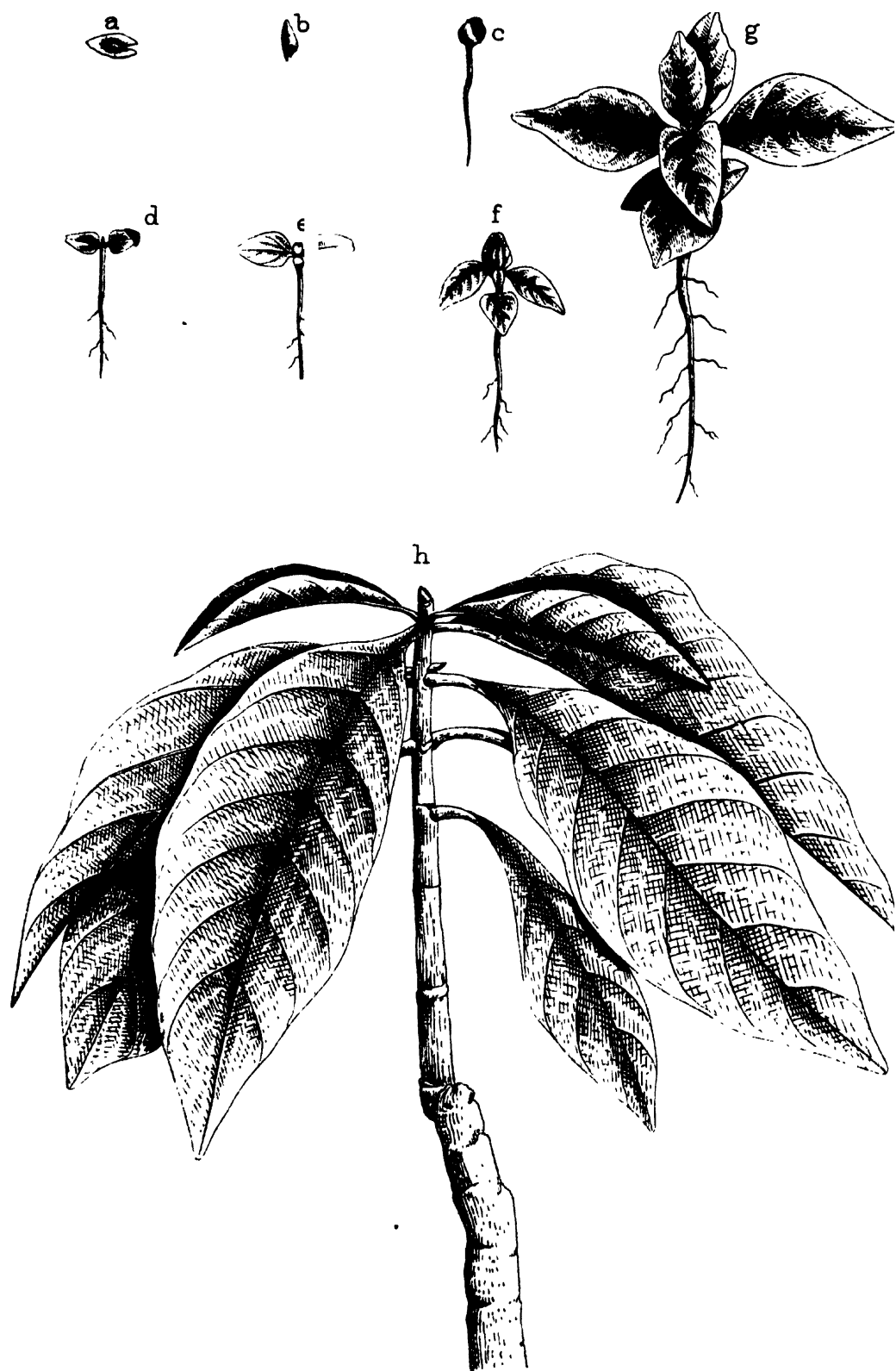


FIG. 240. *Hymenodictyon excelsum*. Seedling $\times \frac{1}{2}$.

a, seed; b-e, germination stages; f, g, development of seedling during first season; h, seedling towards end second season (long thick taproot not shown).

GERMINATION (Fig. 240, b-e). Epigeous. On the emergence of the radicle the hypocotyl elongates, carrying above ground the cotyledons enclosed in the testa. On the expansion of the cotyledons the testa usually remains for a time on the end of one of them, ultimately dropping to the ground.

THE SEEDLING (Fig. 240).

Roots : primary root long, thickening early and becoming very thick in second season, terete, tapering : lateral roots few to numerous, fibrous. *Hypocotyl* distinct from root, 0.3-0.5 in. long, cylindrical, green, minutely pubescent. *Cotyledons* : petiole up to 0.1 in. long, flattened above : lamina 0.35-0.5 in. by 0.25-0.3 in., foliaceous, ovate, emarginate, entire, glabrous, usually persisting till end of first season. *Stem* erect, minutely pubescent, in first season short, with internodes 0.1-0.2 in. long ; in second season thick, woody, with internodes 0.4-1 in. long. *Leaves* simple, opposite decussate : stipules (first season) less than 0.1 in. long, triangular, pubescent : petiole (first season) 0.1 in. long, pubescent, midrib running prominently down upper side : lamina (first season) 0.8-1.8 in. by 0.6-1 in., sub-rhomboidal or ovate, acute, base tapering, entire, pubescent, venation arcuate, lateral veins 4-6 pairs, midrib often red.

The seedling develops very slowly above ground during the first season, and under natural conditions also during the second or third seasons, after which, if the plant survives, the growth is more rapid. As a rule a height of not more than 1 or 2 in. is attained during the first season, with not more than three to five pairs of leaves. The underground development, however, is considerable, a long stout taproot being quickly formed ; this may be as much as 1 ft. 6 in. long by the end of the first season. This underground development, which is common among seedlings of trees characteristic of dry types of forest, is evidently an adaptation for the establishment of the plant before any marked growth in the stem begins.

The seedling is very sensitive to frost, especially during the first year or two while the plants are small ; in localities subject to frost many seedlings are killed outright, while some may shoot up again from the base. Weeds impede the development of seedlings considerably, suppressing and killing them if heavy. The seedling is decidedly light-demanding. Growth ceases from November to May ; the leaves turn yellow or reddish and drop in November-December, the plants being leafless from January to May, when the new leaves appear (northern India).

The following measurements in experimental plots at Dehra Dun give some indication of the rate of growth of young plants :

Hymenodictyon excelsum : development of seedlings, Dehra Dun.

Condition under which grown.	Height at end of season.			
	1st season.	2nd season.	3rd season.	4th season.
(1) Natural conditions	Maximum 0 ft. 1 in.	..	..	..
(2) Nursery, weeded and watered	.. 0 ft. 1½ in.	Maximum 1 ft. 3 in.	..	..
(3) Broadcast sowing, irrigated, unweeded	.. 0 ft. 2 in.	.. 0 ft. 3 in. ¹	Killed by weeds in 3rd season	..
(4) Broadcast sowing, un-irrigated, unweeded	.. 0 ft. 1½ in.	.. 0 ft. 1½ in. ¹	Ditto	..
(5) Broadcast sowing, un-irrigated, weeded	.. 0 ft. 2 in.	.. 0 ft. 4 in. ¹	10 in.-2 ft. 4 in.	Maximum 5 ft. 0 in.

¹ New shoots from base ; seedlings killed back by frost in previous winter.

SILVICULTURAL CHARACTERS. Except that the tree is known to be a strong light-demander its silvicultural characters have not been studied in detail.

NATURAL REPRODUCTION. Germination takes place during the rainy season. Bare ground is favourable to germination and subsequent survival, young seedlings being killed off in quantity where weeds are present. The small seedlings are liable to be washed away by heavy rain during and after germination, the seed is liable to destruction by insects, while the slow development of the seedling and its sensitiveness to weeds, frost, and shade are all contributory factors towards failure of natural reproduction, which explains to some extent its comparative scarcity in many localities.

ARTIFICIAL REPRODUCTION. The artificial propagation of this tree is not easy. Direct sowings are not very suitable owing to the liability of the seed to be washed away and to the slow development of the seedling. Seed should be sown in the nursery in April and May in porous sandy loam, and lightly covered; the seedlings begin to appear in about eight to ten days. The beds require protection from heavy rain. The seedlings should be pricked out when about two or three months old and protected from frost in the winter. The more vigorous plants will be ready to plant out during the following rainy season, but the smaller ones should be kept another year in the nursery. Care is necessary to retain earth round the roots during transplanting, which may possibly be found more successful with the aid of long baskets or bamboo tubes.

RATE OF GROWTH. There are no detailed measurements available, but a cross-section from the United Provinces in the silvicultural museum at Dehra Dun had 41 rings for a girth of 3 ft. 11 in., giving a mean annual girth increment of 1.15 in., which is fairly fast.

6. WENDLANDIA, Bartl.

Wendlandia exserta, DC. Vern. *Chaulai*, *chila*, Hind.

A small deciduous or evergreen tree with greyish pubescent foliage, found locally in the sub-Himalayan tract, outer Himalaya, Chota Nagpur, and parts of the Indian Peninsula. It comes up gregariously on newly exposed ground, particularly on landslips and abandoned cultivation; the minute seeds appear to require such ground for successful germination. The tree is a useful one for reclothing bare hill slopes and clearings. It is strongly light-demanding. The growth is fast: Gamble's specimens gave 4 to 5 rings per inch of radius, or a mean annual girth increment of 1.26 to 1.57 in.

7. GARDENIA, Linn.

This genus contains about eleven Indian species of small trees or shrubs, most of which are interesting as being common members of dry open types of forest on poor ground on which many species are unable to exist. The wood of these trees deserves to be better known as a substitute for boxwood, being hard, close grained, and compact. The most widely distributed species is *G. turgida*, Roxb., described below. The species best known in the Indian Peninsula are *G. lucida*, Roxb., *G. gummiifera*, Linn., and *G. latifolia*, Aiton. These are small trees or shrubs of xerophytic habit, growing on dry poor ground

often consisting of hard clay with quartz pebbles or calcareous nodules; they exude a clear fragrant yellow protective gum-resin which envelops the leaf-buds. The seeds of *G. latifolia* sometimes germinate in crevices in boulders and in forks or hollows of trees, and the plants grow and persist in such places: one plant was noticed in the Singhbhum district growing out of the side of a hollow *Bridelia retusa* tree about 10 ft. from the ground, appearing at first sight as if it had been grafted; the roots penetrated the inside of the *Bridelia* down to the ground.

In Burma various species of *Gardenia* are characteristic of *indaing* (dry dipterocarp) forest on laterite, or of open dry scrub forests; the better-known Burmese species are *G. turgida*, Roxb., *G. coronaria*, Ham., *G. erythroclada*, Kurz, *G. obtusifolia*, Roxb., and *G. sessiliflora*, Wall.

The gardenias are characterized by very fragrant tubular white flowers which appear mainly in the hot season and turn yellowish before falling. The fruits are fleshy, and those of some species at least are eaten by birds and animals, the seeds being disseminated by their agency. Sometimes dense clusters of young seedlings may be found on the ground, having sprung from seed which has germinated within the remains of fruits which have fallen from the tree.

The gardenias are comparatively immune from damage by grazing, and in grazed areas tend to become dominant owing to the extent to which most other species are kept down.

The rate of growth is slow to moderate. Gamble's specimens showed for *G. coronaria* 14 rings per inch of radius, giving a mean annual girth increment of 0.45 in., and for *G. latifolia* 8 rings per inch of radius, giving a mean annual girth increment 0.78 in. A cross-section of *G. latifolia* 1 ft. 0½ in. in girth in the silvicultural museum at Dehra Dun had 28 rings, giving a mean annual girth increment of 0.44 in. A tree of the same species measured for a period of eight years in a sample plot in the Balaghat district, Central Provinces, showed a mean annual girth increment of 0.23 in.

Gardenia turgida, Roxb. Vern. *Thanela*, *karamba*, *ghurgia*, Hind.; *Bengeri*, Kan.; *Thaminsa-ni*, Burm.

A small deciduous tree with light grey or whitish smooth bark, rigid branches armed with sharp straight thorns, and leaves crowded at the ends of the branches. Wood hard, close grained, whitish.

DISTRIBUTION AND HABITAT. Throughout the greater part of India and Burma in dry open deciduous forests, ascending the outer Himalaya to 4,000 ft. The tree is characteristic of poor dry stony soil, dry rocky hill-sides, laterite, *kankar*, and also of stiff clayey soil. In Burma it is common in open *indaing* forests on laterite, in the open scrub forests of the dry zone, and in the dry deciduous forests of the Shan hills and elsewhere.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The old leaves are shed about March, the new foliage appearing about May. The white dimorphic flowers, the females larger than the males, appear chiefly in March–April, when the trees are leafless or nearly so, and the fruits ripen and fall during the hot season a year later. The fruits are sub-globose, 1.5–3 in. in diameter, greyish green, with a thick rather hard pericarp and a woody endocarp, containing numerous angular seeds (Fig. 241, *a*) embedded in pulp. The germina-

tive power of the seed is fairly high : tests carried out at Dehra Dun gave a fertility of 77 per cent.

GERMINATION (Fig. 241, *b-g*). Epigeous. The radicle emerges from one end of the seed ; the hypocotyl elongates by arching, and in straightening raises above ground the cotyledons enclosed in the testa, which falls to the ground on their expansion.

THE SEEDLING (Fig. 241).

Roots : primary root moderately long, at first thin, afterwards thickening, terete, tapering : lateral roots few to moderate in number, fibrous, distributed down main root. **Hypocotyl** distinct from root, 0.6-1 in. long, terete, tapering upwards, white turning green, minutely pubescent. **Cotyledons** : petiole less than 0.1 in. long, flattened above, minutely pubescent : lamina 0.8-0.9 in. by 0.5-0.6 in., foliaceous, ovate, acute, entire, green, glossy and glabrous above, glaucous and glabrescent or minutely pubescent beneath, margins sometimes fringed with fine hairs, venation arcuate. **Stem** erect, slightly compressed, pubescent, in first season short, with internodes up to 0.3 in. long. **Leaves** simple, opposite, sub-sessile or with short petioles bordered by the decurrent leaf-base : lamina up to 1 in. by 0.5 in., ovate, elliptical, obovate or oblanceolate, acute, base decurrent, entire, coriaceous, dark green and glossy above, paler beneath, both surfaces sparsely pubescent, margin with a fringe of fine hairs. Usually not more than two pairs of foliage leaves are produced in the first season.

The growth of the seedling during the first season is very slow, a height of only 1-2½ in. being attained. In the second season it is more rapid : nursery-raised seedlings at Dehra Dun attained a height of 1½ to 4½ ft. by the end of the second season, but under natural conditions, which are more unfavourable, the growth is probably much slower. The seedlings are decidedly frost-hardy.

SILVICULTURAL CHARACTERS. The tree is decidedly hardy as regards both frost and drought. On low-lying grassy land subject to severe frosts it is often one of the few species capable of existing. In the abnormal drought of 1907 and 1908 in the forests of Oudh it escaped injury when many other species were killed off in quantity. It is not readily browsed, even by goats.

NATURAL REPRODUCTION. The fruits are eaten by birds and animals, and the seeds are scattered by their agency. Those which are not eaten lie on the ground, turning brown and drying up somewhat in the hot season, and becoming partially eaten by white ants, or gradually rotting in the rainy season ; in this case most if not all of the seeds lie ungerminated until the second rainy season, when germination takes place.

ARTIFICIAL REPRODUCTION. There is little difficulty in raising this species in the nursery and transplanting it. The seed should be sown about March or April : germination is rather slow, the seedlings usually appearing about six weeks to two months or more after sowing. The seedlings should be pricked out during the first rainy season and transplanted early in the second rains.

RATE OF GROWTH. The growth is slow to moderate. A cross-section from the United Provinces in the silvicultural museum at Dehra Dun showed 37 rings for a girth of 2 ft. 1½ in., giving a mean annual girth increment of 0.7 in. Gamble's specimens averaged 13 rings per inch of radius, giving a mean annual girth increment of 0.48 in.



FIG. 241. *Gardenia turgida*. Seedling $\frac{1}{2}$.
 a, seed ; b-g, germination stages ; h, i, development of seedling to end of first season.

8. *RANDIA*, Linn.

This genus contains about fifteen Indian species of shrubs or small trees, some armed and others unarmed, some evergreen and others deciduous. Most of them have hard whitish close-grained woods suitable as substitutes for boxwood. The two species most commonly met with are *R. uliginosa*, DC., and *R. dumetorum*, Lam. A third, *R. malabarica*, Lam., is a thorny evergreen shrub common in the dry scrub forests in parts of the Indian Peninsula, often on laterite.

The better-known species of *Randia*, unlike the gardenias, appear to be very subject to browsing, especially by goats; this is certainly the case with *R. dumetorum*, *R. malabarica*, and *R. tetrasperma*, Roxb., a Himalayan species which is browsed down to a dense compact bush.

Species 1. *R. uliginosa*, DC.; 2. *R. dumetorum*, Lam.

1. *Randia uliginosa*, DC. Syn. *Gardenia uliginosa*, Retz. Vern. *Pindara*, Hind.; *Hmanbyu*, Burm.

A small deciduous rigid armed tree with reddish brown bark and quadrangular branches, common throughout the greater part of India and Burma, particularly on low-lying swampy ground and savannah lands; also on black cotton soil in the Indian Peninsula. It produces root-suckers freely, and is hardy against frost and drought; in the abnormal drought of 1907 and 1908 in the forests of Oudh it escaped untouched. The tree is leafless as a rule from February to April. The fruit, which ripens about February–March (northern India), is an ellipsoidal berry, 2–2.5 in. long, yellow when thoroughly ripe, with about twelve seeds embedded in a somewhat soft pulp (the swollen placentas) in two cells within a somewhat leathery pericarp. The seeds are dark brown, hard, shining, obscurely angular, 0.15–2 in. long. The growth of the young seedling is very slow. At Dehra Dun a height of less than 1 in. was attained by the end of the first season; by the end of the third season, however, plants attained a height of 7 ft. The rate of growth is moderate. A cross-section in the silvicultural museum at Dehra Dun showed 56 rings for a girth of 2 ft. 7½ in., giving a mean annual girth increment of 0.56 in. Gamble's specimens gave 6 to 7 rings per inch of radius, representing a mean annual girth increment of 0.9 to 1.05 in.

2. *Randia dumetorum*, Lam., including *R. longispina*, DC., and *R. nutans*, DC. Vern. *Mainphal*, Hind.; *Sethanbaya*, *thaminsa*, Burm.

A large shrub or small tree armed with straight axillary thorns and leaves in fascicles along the branches, extremely common as an undergrowth species in the sal forests of the sub-Himalayan tract, and common also in many parts of the Indian Peninsula and Burma, where it extends into the dry zone. It is a drought-hardy species, having resisted well the abnormal drought of 1907 and 1908 in the forests of Oudh. It is readily browsed by goats. It produces root-suckers. The fruit is a globose or ovoid berry, 1–1.5 in. long, yellow when ripe, containing a number of more or less angular seeds embedded in pulp; the fruits ripen in the cold season. As regards rate of growth, a cross-section in the silvicultural museum at Dehra Dun showed 26 rings for a girth of 1 ft. 4 in., giving a mean annual girth increment of 0.62 in. Gamble's specimens averaged 7 rings per inch of radius, representing a mean annual girth increment of 0.9 in.

ORDER XXXIV. ERICACEAE

This order is not of great importance in Indian forestry, though two species, *Rhododendron arboreum*, Sm., and *Pieris ovalifolia*, D. Don., are familiar trees in the Himalaya and other hill regions, where they are useful in clothing hill-sides and acting as nurses to more valuable species. All the Indian species of this order, of which at least forty belong to the genus *Rhododendron*, are trees or shrubs of the hills, many ascending to high elevations.

Genera 1. RHODODENDRON, Linn. ; 2. PIERIS, D. Don.

1. RHODODENDRON, Linn.

Rhododendron arboreum, Sm. Vern. *Chahan*, Haz. ; *Chiu*, *buráns*, W. Him. ; *Zalatni*, Burm.

A small evergreen tree, often with a somewhat crooked or gnarled trunk. Bark soft, easily cut through with a pocket-knife, 0.5-1 in. thick, old bark grey, exfoliating in irregular longitudinal plates, exposing the smooth pinkish new bark beneath. The wood is of inferior quality, both as timber and as fuel.

DISTRIBUTION AND HABITAT. This is a common tree in the western Himalaya, occurring chiefly at 5,000-8,000 ft. in association with *Quercus incana* and *Pieris ovalifolia*, and at the lower elevations with *Pinus longifolia*, but ascending to 11,000 ft. or even higher. It is somewhat rare in Hazara, being commonest in the Siran *Pinus longifolia* forests at 4,000 ft. and upwards in moist ravines. It extends to the eastern Himalaya, where, however, it is less common ; it is also found in the Khasi hills and the hills of Burma, southern India, and Ceylon.

FLOWERING AND FRUITING. The large showy crimson, sometimes pink, flowers in dense corymbs appear usually from March to May, but in certain years only partial flowering takes place then, and a second flowering takes place in June or July ; this happened in the Simla hills in 1916, following an exceptionally dry winter and spring, and the flowers of the second bloom were paler in colour than usual. Similar late flowering is also said to take place if the first bloom is checked by hail or other injury. Occasionally trees may be seen in flower in January-February. The fertilization of the flowers is carried out partly by insects. Mr. G. B. F. Muir notes an interesting case observed in Tehri Garwhal of Indian martens (*Martes flavigula*) visiting one cluster of flowers after another and thrusting their noses into the flowers to lick up the nectar ; fertilization is thus carried out by their agency, and possibly birds may also be agents in cross-fertilization.

The capsules (Fig. 242, a) are 0.8-1.1 in. long by 0.3-0.4 in. in diameter, oblong, curved, greenish brown when ripening, then turning brown. They contain a large number of minute dark brown compressed oblong seeds about 0.05 in. long, with a fimbriate tuft at either end (Fig. 242, b). The capsules open and shed their seeds chiefly from January to March (western Himalaya). The open capsules as a rule remain many months on the tree.

GERMINATION (Fig. 242, c-e). Epigeous. The radicle emerges from one end of the seed and descends. The hypocotyl elongates, arching slightly, and

the testa is carried above ground over the cotyledons, falling to the ground with their expansion.

THE SEEDLING (Fig. 242).

Roots: primary root terete, tapering, short and delicate for about two years, subsequently long and wiry: lateral roots at first few, short, afterwards numerous, moderately long, fibrous, distributed down main root.

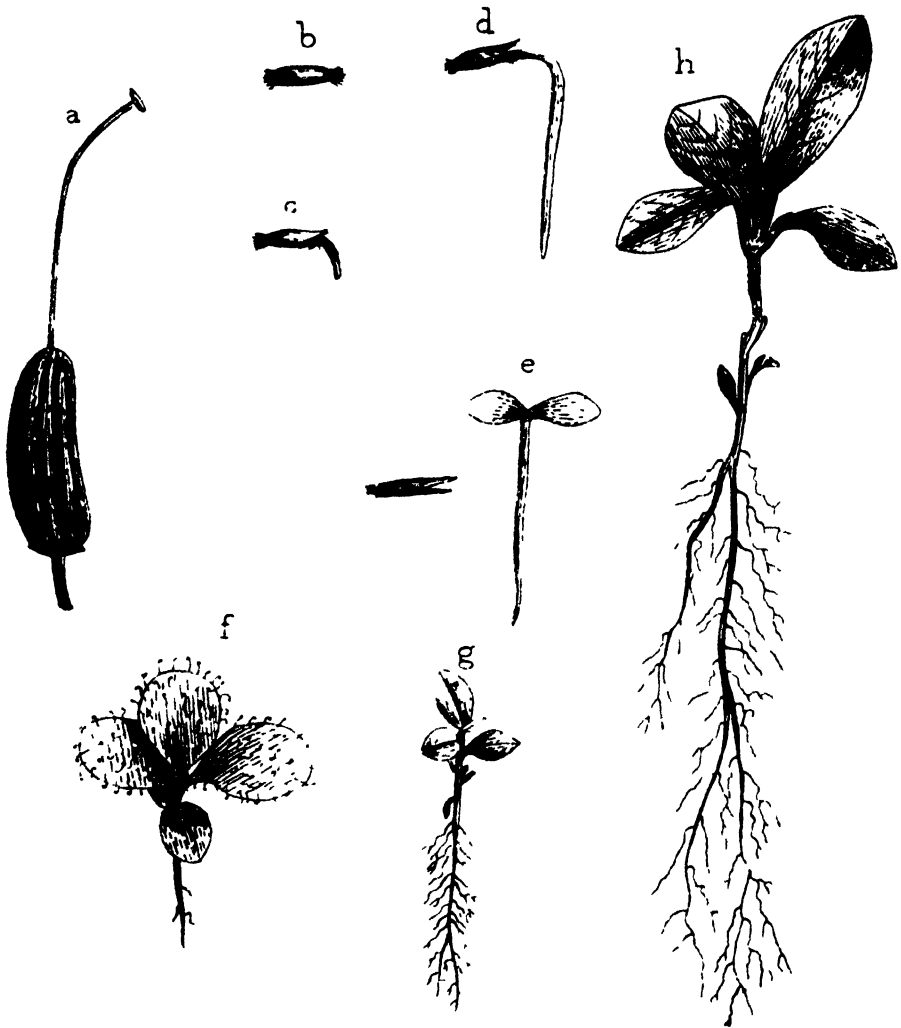


FIG. 242. *Rhododendron arboreum*. Seedling.

a, capsule $\frac{1}{2}$; *b*, seed $\times 5$; *c-e*, germination stages $\times 5$; *f*, seedling towards end of first season $\times 5$; *g*, seedling in third season $\frac{1}{2}$; *h*, seedling in fourth season $\frac{1}{2}$.

Hypocotyl distinct from root, up to 0.1 in. long, terete, cylindrical or tapering slightly upwards, green, glabrous. *Cotyledons* up to 0.06 in. by 0.04 in., foliaceous, slightly fleshy, sub-sessile, elliptical or almost orbicular, acute, obtuse or rounded, minutely and somewhat widely serrulate, often turning red in the autumn. *Stem* erect, very short during first two years, elongating slowly during the next few years. *Leaves* simple, alternate, in first season shortly petiolate, up to 0.12 in. by 0.1 in., broadly ovate or orbicular, mucronate, entire, upper surface and margins covered with stiff glandular hairs,

leaves sometimes turning dark red in autumn : leaves gradually increase in size from second season onwards, becoming elliptical, coriaceous, entire, the upper surface and margins still covered with stiff glandular hairs, at any rate on young leaves, for the first three or four years.

During the first season the seedling is minute, reaching a height of scarcely 0.1 in., with 2 or 3 foliage leaves besides the cotyledons. For the first few years the growth is very slow. The seedling is very sensitive to drought, and survives in moist well-drained places, such as damp shady banks, cuttings, and rocks.

SILVICULTURAL CHARACTERS. The tree stands a fair amount of shade, but develops best in the open. It will grow on rocky ground provided there is sufficient soil moisture, but thrives best on moist loam. It coppices well.

NATURAL REPRODUCTION. Natural reproduction springs up readily on newly exposed ground such as road-cuttings and landslips and in the crevices of bare rocks. In such places seedlings of various ages may often be found in large quantities provided the soil is moist ; natural reproduction does not appear in dry places, as the seedlings perish quickly from drought.

ARTIFICIAL REPRODUCTION. Seedlings may be raised artificially by sowing seed in March or April in boxes or pots filled with fine sand or powdered brick previously soaked with water ; the seeds should not be covered. The boxes or pots should be sheltered from rain and sun and watered regularly. The seedlings may be pricked out, if large enough, in the second season, and kept in the nursery until sufficiently large to plant out.

A more satisfactory method of planting is to dig up seedlings from the banks and cuttings on which they spring up naturally and transfer them to the nursery, keeping them there until large enough to plant out.

RATE OF GROWTH. The annual rings are not always distinct, but where visible they show a slow rate of growth. Brandis gives 14 rings per inch of radius, while Gamble's specimens varied from 12 rings in the western Himalaya and the Nilgiris to as many as 36 in Sikkim, representing a mean annual girth increment varying from 0.17 to 0.52 in.

Coppice growth, though usually faster for a time than that of *Quercus incana*, is slow. Measurements made in 1911 in a coppice coupe six years old at Bhowali near Naini Tal (elevation 5,600 ft.) showed an average of 5 shoots per stool and a mean height of 4 ft. 4 in.

2. PIERIS, D. Don.

Pieris ovalifolia, D. Don. Syn. *Andromeda ovalifolia*, Wall. Vern. *Ayar*, Hind. ; *Ailan*, Pb.

A small deciduous tree. Bark brown, thick, fibrous, exfoliating in long narrow strips, deeply furrowed longitudinally, the furrows often proceeding spirally up the stem. This is a familiar tree in the western Himalaya at 4,000–8,000 ft., chiefly on grassy slopes in association with *Quercus incana* and *Rhododendron arboreum*, or at the lower elevations with *Pinus longifolia*. In Hazara it is rare except in the *Pinus longifolia* forests of the Siran valley, where it is fairly common at 4,000 ft. and upwards. It is also found in the eastern Himalaya, descending to 2,000 ft. in the Tista valley, the Khasi hills, and the hills of Burma. The wood is of little value either as timber or as fuel.

but the tree is useful in covering hill slopes, and in the western Himalaya in acting as a nurse to the deodar. It is fire-resisting and is not browsed by cattle: the leaves are said to be poisonous to goats and camels. The racemes of heath-like white honey-scented flowers appear from April to June (western Himalaya), and the capsules, containing numerous minute seeds, begin to ripen about December, dehiscing from January to March. The tree coppices well, the coppice growing faster than that of *Quercus incana*. Measurements in 1911 in a coppice coupe six years old at Bhowali near Naini Tal showed an average of 8 shoots per stool and a mean height of 5 ft. 1 in., as compared with 4 ft. 3 in. for the oak. Gamble gives the rate of growth as 12 to 18 rings per inch of radius in the west, representing a mean annual girth increment of 0.35 to 0.52 in., and about 6 rings in the east, representing a mean annual girth increment of 1.05 in.

ORDER XXXV. MYRSINACEAE

AEGICERAS, Gaertn.

Aegiceras majus, Gaertn. Syn. *A. corniculata*, Blanco. Vern. *Kulsi*, Beng.; *Kanjala*, Mar.; *Butalet*, Burm.

A large evergreen glabrous shrub or small tree with grey bark, common in the mangrove forests along tidal creeks, where it is frequently gregarious. It is one of the most widely distributed species of this formation, occurring at the mouth of the Indus, along both sides of the Indian Peninsula, in the Sundarbans and along the coasts of Chittagong, Arakan, Burma, and the Andamans. Like the true mangroves this tree exhibits vivipary, the seed germinating within the pericarp of the curved horn-shaped fruit. The tree coppices well. The wood is used for small building material and for fuel.

ORDER XXXVI. SAPOTACEAE

An important order of forest trees, some furnishing useful timbers, others edible flowers and fruits and oil-seeds, others latex of commercial value. The two genera of most importance in Indian forestry are *Bassia* and *Mimusops*. The gutta-percha of commerce is furnished by the latex of certain species of *Palaquium* (syn. *Dichopsis*, *Isonandra*) and *Payena*, found in the Malay Peninsula and Archipelago; both these genera are represented in India, though none of the Indian species are known to yield gutta-percha of good quality. The two most important gutta-percha producing species in the Malayan region are *Palaquium Gutta*, Burck., and *P. oblongifolium*, Burck.

An interesting account of the gutta-percha forests of the Malay States is given in the *Indian Forester*, vol. xxxi (1905), p. 309, by Mr. A. M. Burn-Murdoch, who points out that gutta-percha is derived almost entirely from trees growing within 6 or 7 degrees of the Equator. Apart from the two species of *Palaquium* already mentioned, gutta-percha of good quality is yielded by *Payena Laerii*, which species, however, is not abundant. An inferior latex is produced by *Palaquium pustulatum*. Referring to *P. Gutta*, including *P. oblongifolium*, which is very similar and is not always considered to be

specifically distinct, Mr. Burn-Murdoch notes that the tree is easily recognized by its leaves, which are coriaceous, oblong or obovate-oblong, about 2 in. long in mature plants but much longer in young plants, dark glossy green above and a beautiful coppery gold colour beneath. The tree occurs most frequently on the low hills and plains, often on steep hill-sides, up to 2,000 ft. and even 3,000 ft. above sea-level. During the latter half of last century the trees large enough to yield gutta-percha were practically exterminated; from about 1898 onwards steps were taken to conserve the existing stock, which, however, was by that time found to consist of little except immature trees. The tree is a pronounced shade-bearer and is able to maintain the struggle for existence successfully, if slowly, in the dense evergreen forests in which it grows. Its growth is slow. Natural seedlings are often plentiful, but in the overworked areas many of the young plants are found to be coppice-shoots.

At the time Mr. Burn-Murdoch wrote regular plantations were found to be impossible in the Federated Malay States for want of seed, and the method followed by the Forest Department was to cut lines through the dense undergrowth and to transplant into these lines young natural seedlings taken from outside the reserved forests or from congested clumps of reproduction within those forests. In addition improvement fellings are carried out to assist poles and saplings, and undergrowth is cleared once a year or at longer intervals, as may be found necessary, over natural seedlings or transplants: these measures have been found to produce very beneficial results. The chief damage to this tree is caused by the larva of a moth (*Rhodoneura myrsusatis*, Wlk. ?) which eats the young shoots and leaves; the damage is more extensive in pure plantations than in the case of isolated plants under natural conditions.

Genera 1. *MIMUSOPS*, Linn.; 2. *BASSIA*, Linn.

1. *MIMUSOPS*, Linn.

Species 1. *M. Elengi*, Linn.; 2. *M. hexandra*, Roxb.; 3. *M. littoralis*, Kurz.

1. *Mimusops Elengi*, Linn. Vern. *Mulsári*, Hind.; *Bukal*, Beng.; *Owli*, Mar.; *Bukul*, Kan.; *Mahila*, *magadam*, Tam.; *Elengi*, Mal.; *Kaya*, Burm.

A large evergreen tree with a dense crown of shiny coriaceous leaves with undulate margins. Bark dark grey, scaly. Wood very hard, with dark red heartwood, heavy, strong, and durable, used for building, rice-pounders, &c. The fruit is eaten and the seeds yield an oil used for cooking and lighting and in medicine. Under favourable conditions the tree reaches large dimensions, with a long cylindrical bole.

DISTRIBUTION AND HABITAT. The Indian Peninsula along the Western Ghats from Bombay southwards, and on the east from the Northern Circars southwards, the Andamans and Burma, in Martaban and Tenasserim; also in Ceylon. The tree is fairly common in the moist evergreen forests of the Western Ghats, where it attains large dimensions; on the Eastern Ghats it is found in the dry evergreen forests, often on laterite, as a comparatively small tree. In the Andamans it is common in the evergreen and semi-deciduous forests with *Dipterocarpus* spp., *Planchonia andamanica*, *Artocarpus Chaplasha*, *A. Lakoocha*, *Mesua ferrea*, *Hopea odorata*, *Terminalia bialata*, *T. Catappa*, *Lagerstroemia hypoleuca*, and other species. In its natural habitat the absolute

maximum shade temperature varies from 95° to 115° F., the absolute minimum from 50° to 62° F., and the normal rainfall from 30 to 150 in. or more.

The tree is largely cultivated in India and Burma for ornament and for the sake of its fragrant flowers, which are used for making garlands and for distilling into perfume.

FLOWERING AND FRUITING. The fragrant white star-shaped flowers appear from February to April, and the fruits ripen the following year from February to June or later. The fruit (Fig. 243, *a*) is an ovoid orange-yellow one-seeded berry, about 1 in. long. The seeds (Fig. 243, *b*) are elliptical or rhomboidal, compressed, 0.6–0.9 in. by 0.4–0.5 in., brown, smooth, shining, with a hard testa and a soft whitish albumen; about 50–60 weigh 1 oz. The seeds do not retain their vitality long.

GERMINATION (Fig. 243, *c–g*). Epigeous. The hard testa splits in two, exposing the albumen; the radicle emerges, the hypocotyl elongates by arching, and in straightening carries the cotyledons above ground. When the cotyledons expand the testa, or half of it, and the albumen often adhere for a time to one cotyledon before falling to the ground.

THE SEEDLING (Fig. 243).

Roots: primary root long, terete, tapering, wiry, flexuose; lateral roots moderate in number, fibrous, distributed down main root. **Hypocotyl** distinct from root, 1–2 in. long, terete, fusiform or tapering upwards, at first green and finely pubescent, becoming brown and woody. **Cotyledons** sub-sessile, 0.9–1.1 in. by 0.7–0.8 in., foliaceous, broadly ovate, entire, dark green, glabrous, coriaceous, persisting sometimes into the second season. **Stem** erect, terete or slightly compressed, wiry, green, young parts pubescent, older parts glabrous; internodes 0.4–1 in. long. **Leaves** simple, alternate. Stipules minute, subulate. Petiole 0.1–0.15 in. long, flattened above; lamina 1.7–2.3 in. by 0.5–0.8 in., elliptical lanceolate, acute or acuminate, entire; young leaves sparsely pubescent, soon becoming glabrous, coriaceous, shining.

The growth of the seedling is slow, a maximum height of about 3 in. being ordinarily attained by the end of the first season. The seedlings are very sensitive to frost, which, however, is unknown in their natural habitat: they are capable of standing a considerable amount of shade.

SILVICULTURAL CHARACTERS. The tree is a shade-bearer, retaining a full crown under fairly dense shade. Gamble says it appears to reproduce well in shade and to remain small until an opportunity offers for removal of the cover, when it grows up at once. Judging from cultivated trees the growth is slow.

ARTIFICIAL REPRODUCTION. The best method of propagating the tree is to sow the seeds singly in baskets and plant these out bodily when the seedlings are large enough, that is, usually two years after sowing, in the rainy season.

2. *Mimusops hexandra*, Roxb. Syn. *M. indica*, A. DC. Vern. *Khirmi*, Hind.; *Ranjana*, raini, Mar.; *Pala*, *palai*, Tam.; *Palu*, Cingh.

A large handsome tree with a spreading crown and a straight massive bole; the leaves are dark greyish green, shining, with an obtuse or emarginate apex, and are crowded at the ends of the branchlets. Bark rough, dark grey, crimson inside, and exuding drops of milky juice when cut. Wood red, very hard, heavy, tough, and durable, used for house-posts, turnery, oil-presses, and other purposes. The fruits are sweet and edible, and are largely collected

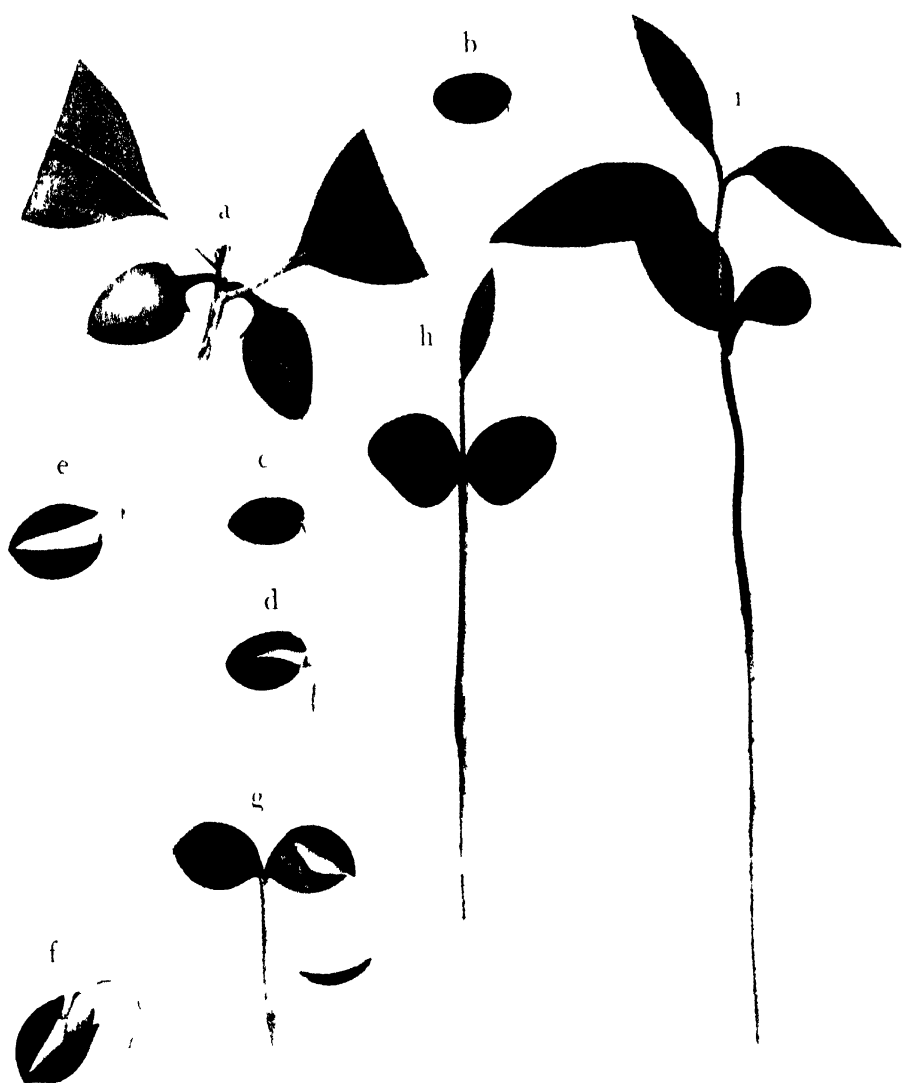


FIG. 243. *Mimosa pudica* SEEDLING $\times \frac{1}{2}$
 -1 fruits b Seed c g Germination stages h i Early development of seedling

for food. Under unfavourable conditions, for example in very dry situations, the tree becomes stunted and even shrub-like.

DISTRIBUTION AND HABITAT. In dry forests of the Deccan, Circars, Orissa, and the Carnatic, extending north to the sandstone of the Pachmarhi hills and west to Khandesh and Guzerat. In the Central Provinces Haines¹ says it is common along sandy *nalas* in North and South Chanda, occurs in the Sirpur range, Raipur, and does well also in lime soils, being common on marl in the Sattara forest.

In the Indian Peninsula it is one of the principal trees of the dry ever-green forests of the Carnatic and surrounding country, especially on sandstone and laterite. In its natural habitat in India the absolute maximum shade temperature varies from 104° to 115° F., the absolute minimum from 32° to 58° F., and the normal rainfall from 25 to 60 in.

It is often cultivated for ornament and for the sake of its fruit.

In Ceylon the tree is of more importance than it is in India. Mr. A. F. Broun,² describing its occurrence and habit in that island, mentions that it is one of the most characteristic and important trees of the dry zone, occurring in the northern half and along the eastern and south-eastern fringes of the island at low elevations in situations having a rainfall of not much over 50 in. It does not occur in the wet zone. In favourable localities it attains a height of 100 ft. with a bole of 40 to 50 ft., but usually not more than 30 ft., and a girth up to 14 or 15 ft. The most favourable soil is a deep sandy loam, but it is found on almost pure sand, on gravel, clayey loam, and soil overlying limestone. On the poor soils of the arid zone it degenerates into a small tree. Among its chief companions in Ceylon are *Diospyros Ebenum*, *D. ovalifolia*, *Chloroxylon Swietenia*, *Berrya Ammonilla*, *Alseodaphne semecarpifolia*, and *Nephelium Longana*.

FLOWERING AND FRUITING. The white or pale yellow flowers appear from November to January and the fruits ripen from April to July. The fruit is an ovoid or ellipsoidal berry, 0.5–0.6 in. long, smooth and red when ripe, containing one reddish brown shining seed, rarely two seeds. Mr. Broun states that in Ceylon good seed-years, which are generally dry years, are very irregular.

SILVICULTURAL CHARACTERS AND NATURAL REPRODUCTION. Mr. Broun makes the following interesting observations regarding this tree in Ceylon: 'It is a curious fact that trees of the lower girth-classes are generally comparatively rare in high forests, but are found more abundantly in old *chenas* (regrowth after temporary cultivation). Enumeration survey figures . . . indicate that the tree does not reproduce itself easily under a dense leaf-canopy. The very appearance of the tree with its large crown, which it spreads out above its companions, shows that it likes to have light in large doses. It is therefore apparent that the seed fellings require to be made heavy. I have noticed that fellings in *palu* forests are not generally followed by the appearance of a seedling crop of that species, although seed-bearers were adjoining the gaps made. This is probably partly due to the great irregularity of the good seed-years, which are generally dry years, but I attribute it also to the following causes. The rainfall being slight, the seed exposed to the

¹ Central Provinces List

² Ind. Forester, xxvi (1900), p. 309.

scorching sun does not readily germinate, and if it does the tender seedling cannot stand the exposure, or it cannot force its roots through the tufts of dense *urru* grass which spring up on exposed patches. Moreover, the seed being edible and lying, as it does, in an exposed place, is soon carried away by animals; it is also removed by villagers in large quantities from the seed-bearers.

‘As mentioned above, *palu* saplings are by no means uncommon in scrub forests; it follows that the young plant requires some low shelter, and this is obtained in high forest by sparing the undergrowth which protects the soil and spares the fruit. Perhaps the best method of carrying on seed fellings is to girdle the trees adjoining seed-bearers.’

RATE OF GROWTH. In Ceylon Mr. Broun estimates from sample plot statistics, which he admits to be scanty and tentative, that a girth of 6 ft. is attained in about 130 years. Owing to the compact and uniform nature of the wood the incremental rings are indistinguishable.

3. *Mimusops littoralis*, Kurz. Andaman bullet-wood. Vern. *Katpali*, Burm.; *Mohwa* (in the Andamans).

A large evergreen tree with leaves crowded towards the ends of the thick branchlets. Bark thin, smooth, blackish brown. Wood red, very hard, durable, used for bridge-construction and house-posts. Common along the coasts of the Andamans, Cocos, and Nicobar islands; also in upper Tenasserim (Kurz). In the Andamans this is a common tree in the mixed forests of the littoral fringe, in association with *Calophyllum Inophyllum*, *Azelia bijuga*, *Thespesia populnea*, *Terminalia Catappa*, *Heritiera littoralis*, *Pongamia glabra*, and others. This type of forest occurs on raised beaches on deposits of sea-sand. *Mimusops littoralis* sometimes predominates, especially where the sand deposit is deep, forming at times almost a pure fringe. It often forms a protective belt against the force of the south-west monsoon, which it possesses good power of withstanding.

2. BASSIA, Linn.

Of the five Indian species of *Bassia* the best known and most widely distributed is *B. latifolia*, Roxb., while in southern India this species is replaced by *B. longifolia*, Linn., an important tree within its region. Both these trees are valuable on account of their flowers, the fleshy corollas of which are eaten or distilled into spirit, and their seeds, which yield oil. *B. butyracea*, Roxb., the seeds of which yield a vegetable butter, is a species met with in the sub-Himalayan tract and outer hills. The oily seeds of the trees of this genus have a high percentage of fertility when fresh, but lose their vitality if kept for any time.

Species 1. *B. latifolia*, Roxb.; 2. *B. longifolia*, Linn.; 3. *B. butyracea*, Roxb.

1. *Bassia latifolia*, Roxb., including *B. villosa*, Wall. Vern. *Mohwa*, Hind.; *Ippi*, Tel.; *Kat illipi*, Tam.

A large deciduous tree, usually with a short bole, spreading branches, and a large rounded crown. Bark grey, with vertical cracks.

This is one of the most important forest trees of India, its importance being due mainly to the fleshy corollas of its flowers, which are eaten raw or



FIG. 244 *Bassia latifolia* tree, with others in background, remaining on former forest land cleared for cultivation, Singhbhum, Chota Nagpur.



FIG. 245. *Diospyros burmanica*, regrowth from root-suckers and coppice-shoots on fields left unworked for four years, Burma.

cooked, or are dried, ground, and mixed with flour for making cakes, or are distilled into spirit. A thick white oil extracted from the seed is used by jungle tribes for cooking and burning, and is sold for the manufacture of margarine, soap, and glycerine. The wood is of good quality, but the tree is seldom felled, owing to the value of its flowers and fruits.

DISTRIBUTION AND HABITAT. Common in the deciduous forests of the Central Provinces, Bombay Presidency, northern parts of the Madras Presidency, Central India, Chota Nagpur, Orissa, and extending north to the sub-Himalayan tract in Oudh, Kumaun, and westward, though not common, to the Ravi. Doubtfully indigenous in Upper Burma. Not found in the southern parts of the Indian Peninsula. Much planted on the plains of northern India and in the Peninsula. The tree is a characteristic one in mixed deciduous forests, usually of a somewhat dry type, often growing on dry rocky or sandy soil, and thriving on the Deccan trap. It is common also in the drier types of sal forest in Chota Nagpur and the Central Provinces. When forest land is cleared for cultivation the *mohwa* trees are carefully preserved, and may be found scattered over cultivated lands long after the clearing has taken place (see Fig. 244).

In its natural habitat the absolute maximum shade temperature varies from 106° to 118° F., the absolute minimum from 30° to 46° F., and the normal rainfall from 30 to 75 in.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The leaves fall gradually from February to April, and the new leaves appear about April or early May, with or shortly after the flowers. Fig. 244 shows a tree in March, partly bare of leaves. The new leaves are conspicuous from their coppery red colour. The brown flower-buds appear at the ends of the thick branchlets early in February, and the flowers open from the end of February to April. The corollas are 0.5–0.6 in. long, cream-coloured, fleshy, and sweet, and fall soon after opening. They are collected in large quantities off the ground, usually in places swept bare under the trees; they are also eagerly devoured by bears, deer, and other animals. The fruit, which is ovoid, fleshy, greenish, 1–2 in. long, 1- to 4-seeded, ripens from June to August, and falls at once to the ground. The seeds (Fig. 246, *a*) are 0.8–1.3 in. long by 0.5–0.7 in. broad, slightly compressed, ellipsoidal, light brown, smooth, shining, with a moderately hard testa; about 200 weigh 1 lb. on an average.

Fresh seed has a high percentage of fertility, but the seed quickly loses its vitality if kept, and is much subject to insect and fungus attacks. Specimens of a microlepidopterous insect whose larvae were found in large numbers destroying the insides of seeds have been named by Meyrick *Stathmopoda basiplectra*, sp. nov. Seeds attacked by fungi were examined by Dr. Butler, who detected two separate fungi, a *Diplodia*, probably parasitic, and a *Schizophyllum*, probably saprophytic after the seeds had lost their vitality. Affected seeds become rough and blistered, the surface often assuming a silvery colour, and the black pycnidia of the *Diplodia* appearing on the surface. The liability of the seed to attacks of insects and fungi is a matter of importance in so far as natural reproduction is concerned, for, as will be seen later, seed which becomes buried soon after falling germinates without being attacked.

The *mohwa* crop is of great importance to the jungle population, and

good flowering years are eagerly looked forward to. They do not occur every year, but, as far as records go, one to two good crops may be expected every three years. An otherwise promising crop is sometimes destroyed by hail before the flowers are developed. Trees are said to commence bearing crops of flowers and fruit when about ten years old. The yield of *mohua* (corollas) per tree is said to be about a maund (82½ lb.) a year when fifteen years old, increasing to two maunds when in full bearing.

GERMINATION (Fig. 246, b-f). Hypogeous. Germination commences with the development of thick cotyledonary petioles, as in the case of many oaks. These petioles, which are not visible in the seed, reach a length of 0.6-1 in., and assist the radicle to make its way into the ground and the plumule to extricate itself from between the fleshy cotyledons, which are in close contact. The cotyledons remain underground, the testa breaking open as they swell.

THE SEEDLING (Fig. 246).

Roots : primary root long, thick, terete, tapering, light brown and delicate in early stages, soon becoming rough and woody : lateral roots at first few and short, afterwards longer and more numerous, fibrous, distributed down main root. **Hypocotyl** very short, subterranean, white turning green or reddish. **Cotyledons** : petiole 0.6-1 in. long, thick, fleshy, flattened, glabrous : lamina 1 in. by 0.6 in., thick, fleshy, oblong, outer surface convex, inner flat or slightly concave. **Stem** erect, terete, pubescent ; first internode 1-2 in., subsequent internodes 0.5-1.3 in. long. **Leaves** simple, first pair opposite or sub-opposite, subsequent leaves alternate, first few leaves sometimes small and scale-like. **Stipules** 0.15 in. long, linear. **Petiole** 0.1-0.2 in. long, channelled above. **Lamina** 1-4 in. by 0.7-1.5 in., elliptical, oblong or ovate, apex and base acute or more rarely obtuse, entire, glabrous above, slightly pubescent beneath, especially on the veins, young leaves often coppery red.

The growth of the seedling is comparatively slow, and weeding and watering, though they stimulate development to some extent, appear to have a less marked effect on it than is the case with many other species. The following measurements of seedlings in experimental plots at Dehra Dun give some idea of the rate of growth under different conditions :

Bassia latifolia : rate of growth of seedlings, Dehra Dun.

Condition under which grown.	Height at end of season.			
	1st season.	2nd season.	3rd season.	4th season.
In nursery (weeded and watered)	Maximum 0 ft. 5 in.	Maximum 2 ft. 0 in.	..	..
Natural conditions (not weeded or watered) in full sunlight	(1) Maximum 0 ft. 4½ in. (2) 0 ft. 3 in.-0 ft. 7 in.	(1) Maximum 1 ft. 2 in. (2) Maximum 1 ft. 0 in.	(1) Maximum 2 ft. 0 in. ..	
Sowings, irrigated and weeded	0 ft. 1½ in.-0 ft. 5 in.	..	..	..
Sowings, irrigated but not weeded	0 ft. 1½ in.-0 ft. 4½ in.	..	..	..
Sowings, weeded but not irrigated	0 ft. 1½ in.-0 ft. 6 in.	..	0 ft. 6 in.-0 ft. 10 in.	Maximum 3 ft. 6
Nursery-raised transplants (planted out in second rains)	..	Maximum 1 ft. 1 in.	Maximum 1 ft. 4 in.	..

Growth ceases from November to February, the new leaves appearing in March (Dehra Dun). Young plants are somewhat frost-tender.

SILVICULTURAL CHARACTERS. The tree has a large spreading root-system,

many of the roots being superficial. It is capable of thriving on poor dry ground, where, however, it is apt to suffer, sometimes severely, in times of abnormal drought. It is ordinarily frost-hardy, but in the severe frost of



FIG. 246. *Bassia latifolia*. Seedling $\times \frac{3}{8}$.

a, seed ; b-f, germination stages ; g, h, development of seedling during first season ; i, seedling early in second season.

1905 it suffered to some extent in northern India. In its younger stages it is very liable to be browsed by deer and cattle. It is a strong light-demander, becoming readily suppressed under shade. It coppices fairly well if cut in the dry season, but not in the rains. In some localities the tree suffers greatly from the attacks of *Loranthus* ; this is particularly the case in some parts of

the Central Provinces and Central India, where the trees are killed off in large numbers by this parasite, which itself dies after killing its host. Special measures are urgently called for to deal with this pest and to prevent its further spread. Systematic and repeated cutting of the parasite appears to be the only practical method of dealing with it; *mohwa* lessees should be required to do this, and organized efforts should be instituted in the forest, in cultivated lands, and generally wherever the *Loranthus* makes its appearance.

NATURAL REPRODUCTION. The seed germinates early in the rainy season, soon after falling. For successful germination it is important that it should become covered with earth or debris, otherwise the seed is liable to fungus attacks, while the radicle is apt to dry up or to become eaten by insects if exposed. Natural seedlings are thus found chiefly in slight hollows into which earth is washed at the commencement of the rains. Their subsequent growth, which is comparatively slow, is favoured by the admission of abundant light.

ARTIFICIAL REPRODUCTION. The tree may be propagated either by direct sowing or by transplanting from the nursery. For forest purposes direct sowings in prepared lines or patches are preferable, as transplanting gives trouble and is attended with much risk owing to the long and rather delicate taproot developed by the seedling. In either case fresh seed should be sown about July–August, and care should be taken to cover it with earth to a depth of about half an inch.

For transplanting purposes it is preferable either to sow the seed direct in long pots or baskets, or to transplant the seedlings from nursery-beds into pots or baskets during the first rainy season a few weeks after germination. The plants may be put out in the forest early in the second rainy season. While they are in the nursery watering should be somewhat sparingly carried out, and the soil should be kept loose. Plantations should be protected from cattle and deer.

RATE OF GROWTH. Few reliable statistics are available regarding the rate of growth of this important tree. The following measurements are recorded in high forest sample plots :

Bassia latifolia : girth increment in high forest sample plots.

Province.	Forest division.	Locality.	Number of years under measurement.	Number of trees under measurement.	Girth classes.	Mean annual girth increment for period.
					ft.	in.
United Provinces	Gonda	Chandanpur and Sakra	2	5	1½-3	0·61
Central Provinces	Balaghat	Baihar and Raigarh }	8	{ 1 3	1-2 2-3	0·70 0·23

As regards coppice, measurements made in 1911 in the Gonda district, United Provinces, in two coupes each two years old, showed an average height of 4·7 and 10 ft. as compared with 7·6 and 10 ft. for sal. Coppice-shoots one year old measured in Bhandara, Central Provinces, had an average height of 4·25 ft. as compared with 7·1 ft. for teak. Coppice measurements made in 1910 by Mr. C. M. McCrie in Gorakhpur, United Provinces, gave the following results for *Bassia latifolia* as compared with sal :

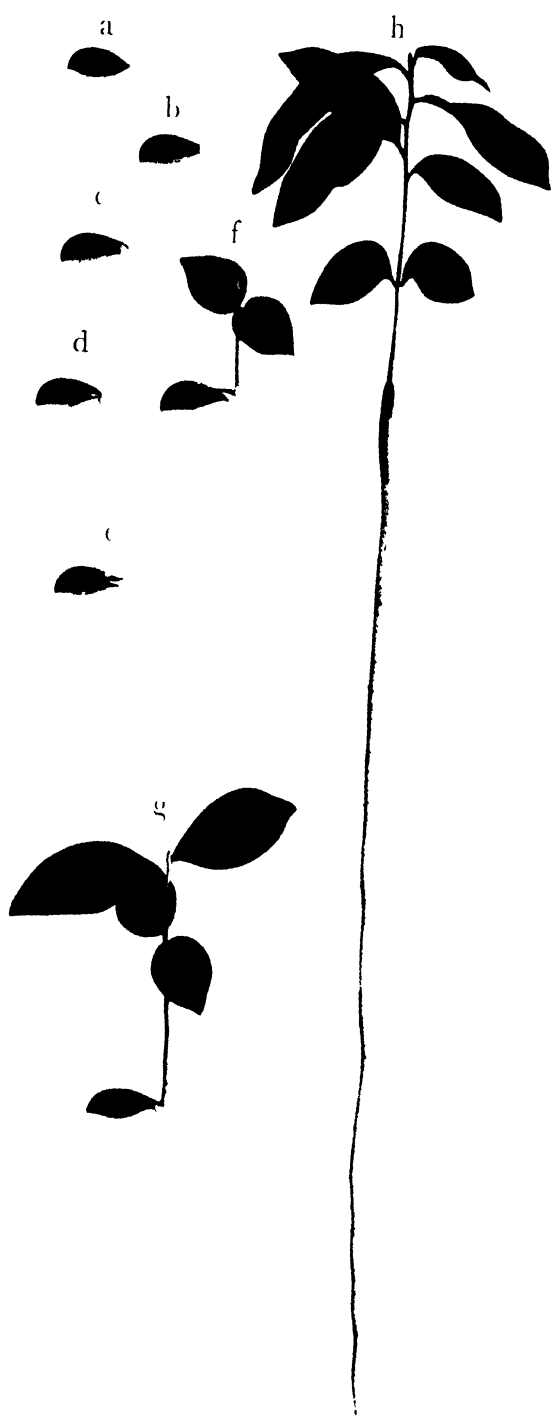


FIG. 247 *Basella longifolia* SEEDLING $\times \frac{1}{4}$

a—Seed b, c—Germination stages f, h—Development of seedling to end of first season

Bassia latifolia : coppice measurements, Gorakhpur.

Age. years.	Mean height.		Mean girth.	
	<i>Bassia</i> , ft.	Sal. ft.	<i>Bassia</i> , in.	Sal. in.
2	7	3	..	..
4	13	7	2.3	2
6	17.5	10.3	3.5	2.9
8	20	13	4.5	3.8
10	22	15.3	5.4	4.8
12	23.6	17.5	6.3	5.8
14	25	19.2	7.2	6.7
16	26.7	20.9	8.0	7.5

2. *Bassia longifolia*, Linn. Vern. *Ippi*, Kan. ; *Pedda ippa*, Tel. ; *Illupei*, Tam. ; *Mèzè*, Burm.

A large evergreen tree with a dense spreading crown and lanceolate leaves clustered at the ends of the branchlets. Bark yellowish grey to brown, red and milky inside. The wood is similar to that of *B. latifolia* : in Arakan it is used for ships' keels and is said to be very durable, resisting the attacks of the teredo. The flowers and seeds are used in the same way as those of *B. latifolia*. It is an excellent avenue tree.

DISTRIBUTION AND HABITAT. This tree replaces *B. latifolia* in southern India. It is indigenous chiefly in the monsoon forests of the Western Ghats from the Konkan southwards, where it is common along the banks of rivers and streams and in ravines : it extends into the Deccan. It is also common in many parts of southern India, where it is frequently cultivated as an avenue tree and for the sake of its flowers and fruits. In Arakan it is said to be indigenous in the Sandoway and Kyaukpyu districts : it is occasionally planted elsewhere in Burma. Although found wild most commonly in rather moist regions, it can be grown in comparatively dry localities.

FLOWERING AND FRUITING. The flowers, which have fleshy corollas like those of *B. latifolia*, appear in November–December in Bombay (Talbot), from February to May in Travancore (Bourdillon). The fruits ripen about June. The seeds (Fig. 247, *a*) are 1.2–1.6 in. long by 0.5–0.7 in. in diameter, compressed, light brown, smooth, shining, with a fairly thick and hard testa ; about 180–200 weigh 1 lb. The fertility of fresh seed is high, but the seeds do not retain their vitality long.

GERMINATION (Fig. 247, *b e*). Hypogeous, and similar to that of *B. latifolia*. It commences with the development of thick cotyledonary petioles, which, however, are not so long as those of *B. latifolia* ; these assist the radicle to make its way into the ground and the plumule to extricate itself from between the fleshy cotyledons. The cotyledons remain underground within the testa.

THE SEEDLING (Fig. 247).

Roots : primary root long, thick, terete, tapering, woody, pubescent when young ; lateral roots moderate in number, fibrous, distributed down main root. *Hypocotyl* distinct from root, 1–1.5 in. long, thick, subterranean. **Cotyledons** : petiole 0.3–0.4 in. long, broad, thick, flattened, somewhat fleshy, bent to one side of stem : lamina 1–1.2 in. by 0.4–0.5 in., thick, fleshy, obliquely oblong, outer surface convex, inner flat. **Stem** erect, terete or slightly compressed, green or reddish, young parts pubescent, later becoming glabrous ;

internodes 0·4–3 in. long. *Leaves* simple, first pair opposite or sub-opposite, subsequent leaves alternate. *Stipules* 0·1–0·15 in. long, linear, pubescent. *Petiole* 0·1–0·2 in. long, pubescent. *Lamina* 1·6–4·5 in. by 1·3–2 in., elliptical or ovate, apex and base acute, or base sometimes obtuse in first pair, entire, pubescent or glabrescent; young leaves often coppery brown; lateral veins 9–16 pairs.

The growth of the seedling is moderate, a height of 6 in. to 1 ft. being attained in the first season and a height of about 1 to 2 ft. being ordinarily attained by the end of the second season. A long but somewhat fragile taproot is developed rapidly, the length being sometimes as much as 1 ft. within a month of germination, and 2 ft. by the end of the first season. Frost is unknown in the natural habitat of the tree; seedlings raised at Dehra Dun were found to be very frost-tender.

ARTIFICIAL REPRODUCTION. In spite of the long fragile taproot the seedlings can be transplanted successfully with care during the first rainy season when about one month old. Fresh seed should be sown about June–July and well covered with earth. The most satisfactory method is to sow the seeds direct in long pots or baskets, or to prick them out into these from the seed-beds when about one month old, and to plant the seedlings out without disturbance of the root-system early in the second rainy season.

3. *Bassia butyracea*, Roxb. Vern. *Phalwara*, *phulwa*, *chiura*, Hind.

A large deciduous tree with leaves somewhat larger than those of *B. latifolia*, and crowded near the ends of the branches. Bark dark grey. The seeds furnish a white vegetable butter.

The tree occurs in the sub-Himalayan tract and outer Himalaya from the eastern Dun eastwards, ascending to 5,000 ft. In the hills it is found chiefly along the sides of ravines. It flowers in the cold season, and the fruits ripen in June–July; the seeds are 0·7–0·8 in. long. The growth is fast. A cross-section 3 ft. 5 in. in girth, without bark, in the silvicultural museum at Dehra Dun had 46 rings, giving a mean annual girth increment of 0·9 in. Gamble's specimens gave three to four rings per inch of radius, representing a mean annual girth increment of 1·57 to 2·1 in.

ORDER XXXVII. EBENACEAE

DIOSPYROS, Linn.

This genus, which contains nearly 50 Indian species, is of importance chiefly as containing the ebony-yielding trees. The true jet-black ebony of commerce is yielded by *D. Ebenum*, Koenig, which is of more importance in Ceylon than in India. The commonest Indian black ebony tree is *D. Melanoxyylon*, Roxb. (including *D. tomentosa*, Roxb.), the heartwood of which, though not so jet black as the true ebony, is used to a considerable extent in India for carving and turning. Of variegated ebonies the best known are the cala-mander wood of Ceylon (*D. quaesita*, Thw.) and the marble-wood or zebra-wood of the Andamans (*D. Kurzii*, Hiern.).

Silviculturally this genus requires further study. Several species thrive in dry regions, for example *D. Melanoxyylon*, *D. burmanica*, *D. Ebenum*,

and others. *D. Embryopteris* goes to the other extreme, thriving on moist and even marshy ground. The fruits are few-seeded berries ; some of them are edible, and are readily devoured by fruit-bats, monkeys, and other animals, as well as by birds, particularly hornbills, and the seeds are scattered by their agency. As a rule the seeds have a high percentage of fertility. The seedlings develop long taproots at an early stage, often before any appreciable elongation of the shoot takes place. A curious creeping habit of the young taproot has been noticed in the case of *D. Melanoxyylon*, *D. montana*, and *D. Chloroxyylon* (see under these species) ; possibly this may also be the case in other species. The growth of the seedling is decidedly slow in all the species hitherto examined. A characteristic of certain species, notably *D. Melanoxyylon* and *D. burmanica*, is the freedom with which root-suckers are produced ; it is doubtful if any other Indian tree surpasses *D. Melanoxyylon* in the profusion, hardness, and tenacity of its sucker reproduction.

To this genus belongs the fruit-tree *D. Kaki*, Linn. f., the persimmon (Japanese *Kaki*, Burmese *Tayók-tè*), which is much cultivated in China and Japan, and occurs wild in the Khasi hills and in Upper Burma. It has been tried in India, and has succeeded fairly well at Dehra Dun, where the fruit ripens towards the end of the rainy season. *D. Lotus*, Linn., vern. *amlak*, Punj., a native of western Asia, extending in the Himalayan region eastward to Kashmir and Hazara, is cultivated for its fruit in the Punjab and in the Mediterranean region : it is frequently cultivated round villages in Hazara.

Species 1. *D. Melanoxyylon*, Roxb. (including *D. tomentosa*, Roxb.) ; 2. *D. Embryopteris*, Pers. ; 3. *D. Kurzii*, Hiern. ; 4. *D. burmanica*, Kurz ; 5. *D. Ebenum*, Koenig ; 6. *D. Chloroxyylon*, Roxb. ; 7. *D. montana*, Roxb. (including *D. cordifolia*, Roxb.) ; 8. *D. ehretioides*, Wall.

1. *Diospyros Melanoxyylon*, Roxb., including *D. tomentosa*, Roxb. Vern. *Tendu*, Hind. ; *Balai*, Kan. ; *Tumki*, Tel.

In his *Forest Flora of North-West and Central India* Brandis unites these two, but in his *Indian Trees* he separates them, while expressing doubt as to their being distinct species. Gamble, in his *Manual of Indian Timbers*, mentions that it is very difficult to distinguish them either in the field or in the herbarium. Haines, in his *List of Trees, Shrubs, &c., of the Southern Circle, Central Provinces*, notes that both varieties occur mixed up and appear to be often indistinguishable, but that in the region dealt with *D. tomentosa* is perhaps more eastern in its distribution : see also his *Forest Flora of Chota Nagpur*. The main botanical distinction consists in *D. Melanoxyylon* having leaves narrower than *D. tomentosa*, with base and apex often acute and secondary nerves raised, while *D. tomentosa* usually has rounded or obtuse leaves and secondary nerves impressed above. So far as the two have been studied silviculturally, their characters appear to be identical, and unless further study should reveal any radical differences they may be united from a silvicultural point of view.

A small to moderate-sized, occasionally large tree, with leaves opposite, sub-opposite, or alternate, coriaceous, and varying much in size and form. Bark greyish black, exfoliating in regular rectangular scales. Wood hard, reddish brown, with an irregular black heartwood sometimes streaked with purple or brown. The wood is used for building, shafts, shoulder-poles, and other purposes, and is carved into walking-sticks, picture-frames, and fancy articles ; when burnt it emits showers of sparks, and is therefore not a safe

fuel. Silviculturally the tree is of importance in clothing dry poor ground, and is interesting owing to its wonderful hardiness in surviving maltreatment.

DISTRIBUTION AND HABITAT. The distribution of *D. Melanoxylon* is stated to be the Indian Peninsula generally, extending northward to Bihar, and that of *D. tomentosa* the sub-Himalayan tract from the Ravi to Nepal, eastern Rajputana, the Central Provinces and Berar, Bihar and Orissa, and the Northern Circars. Both are common in the Central Provinces, and Haines says that the latter is the commoner form in Chota Nagpur, where it is one of the commonest trees throughout the forests. Considering the two forms as one species, this is one of the most characteristic trees of the dry mixed deciduous forests throughout India. It is locally common also in sal forest, often replacing the sal where the ground becomes too poor to support the latter. In the Peninsula it appears to reach its best development on metamorphic rocks.

In its natural habitat the absolute maximum shade temperature varies from 105° to 119° F., the absolute minimum from 30° to 55° F., and the normal rainfall from 20 to 60 in.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The tree is leafless for a short time in the hot season or is frequently never quite leafless. The flowers appear from April to June, and the fruits ripen from April to June the following year. The fruit is a globose to ovoid berry, 1-1.5 in. in diameter, smooth and yellowish when ripe, with 3-8 seeds embedded in a sweet yellow edible pulp. The seeds (Fig. 248, *a*) are oblong, compressed, 0.5-0.8 in. long, brown, shining, with a wrinkled testa and ruminant albumen. About 25 to 40 weigh 1 oz. Fresh seeds have a high percentage of fertility; different samples of seed tested at Dehra Dun after being stored for a year had a fertility of 10, 55, and 60 per cent. respectively. The fruits are readily eaten by fruit-bats and by birds, notably hornbills, which may often be seen in quantity among the trees at the time the fruits are ripening; the seed is spread by their agency.

GERMINATION (Fig. 248, *b-f*). Epigeous. The radicle emerges from one end of the seed and descends rapidly, forming a taproot of some length before the elongation of the hypocotyl is completed. The hypocotyl elongates by arching, and in straightening raises above ground the cotyledons enclosed in the testa and albumen. The cotyledons are caducous, and either they become detached before extricating themselves from the testa and fall to the ground still enclosed in it, or more usually they extricate themselves, the testa falling to the ground, but they fall off not long after.

THE SEEDLING (Fig. 248).

Roots: primary root long, thick, at first fleshy, afterwards woody, black, tomentose, often bent or swollen in upper part near ground-level; lateral roots short, fibrous, distributed down the main root. **Hypocotyl** distinct from root, 1.2-1.6 in. long, slightly compressed or terete, tapering upwards, minutely tomentose, at first smooth and pink with a pale grey or pale yellow base, afterwards rough and reddish brown to nearly black. **Cotyledons** sessile, 0.7-0.8 in. by 0.25-0.3 in., foliaceous, oblong lanceolate, apex acute or rounded, entire, glabrous, delicate, white, pale pink or pale green, caducous, venation reticulate. **Stem** erect, slightly compressed or terete, woody, tomentose; internodes 0.1-0.7 in. long. **Leaves** simple, exstipulate, first pair or sometimes two pairs opposite, subsequent leaves alternate or sub-opposite. **Petiole** about 0.1 in. long, tomentose. **Lamina** 1-2 in. by 0.6-1.2 in., elliptical, ovate

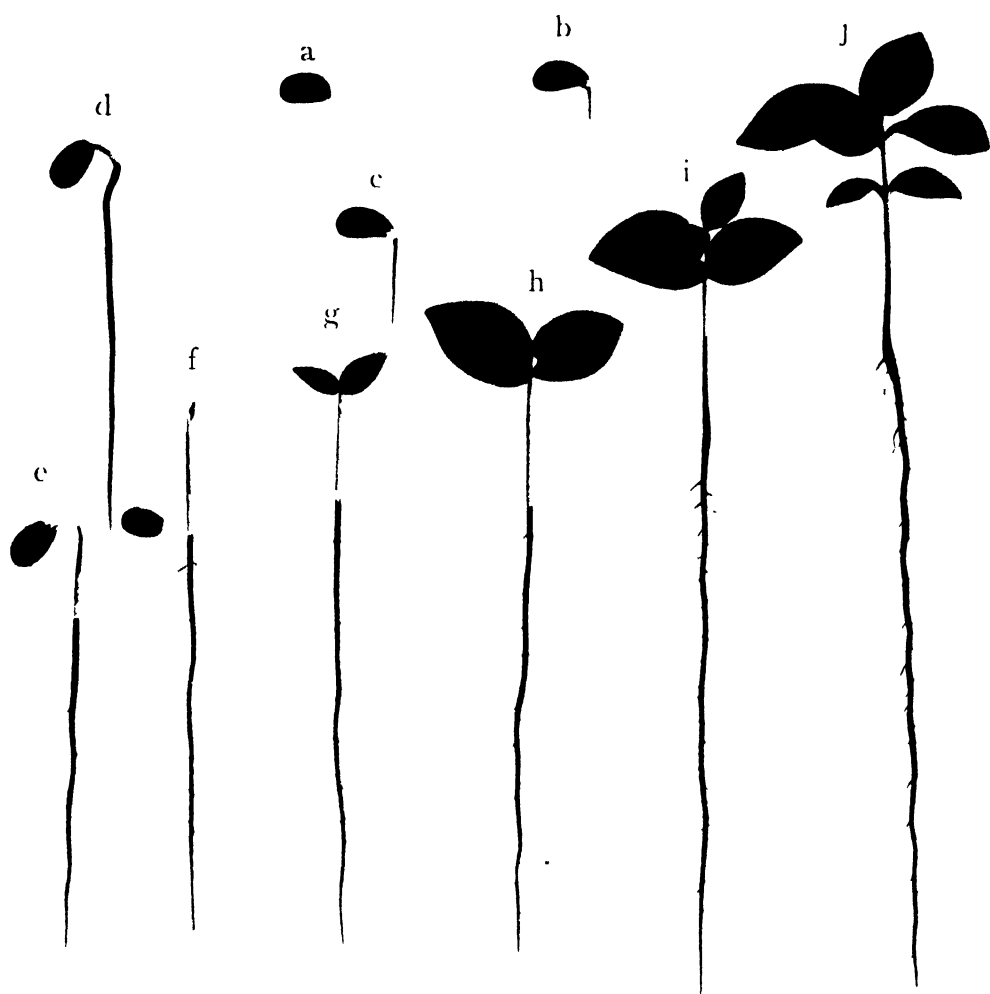


FIG. 248 *Diospyros Melanoxylon*—SEEDLING $\times \frac{3}{8}$

a- Seed b-f—Germination stages g-j—Development of seedling to end of first season

or obovate, apex acute, obtuse or rounded, base rounded or slightly cordate, entire, coriaceous, glabrescent or sparsely pubescent with yellowish hairs, principal veins of lower surface pubescent; older leaves dark green, younger leaves dull reddish green; lateral veins 5 to 10 pairs, in *D. tomentosa* impressed on the upper surface, in *D. Melanoxyton* somewhat variable, but for the most part not impressed.

Note.—This description applies to the seedling both of *D. Melanoxyton* and of *D. tomentosa*.

The main development of the seedling during the first year or two is underground; a long taproot is quickly formed, and may attain a length of 1 ft. or more in a few weeks, and a length of 2 ft. or more with a diameter of nearly $\frac{1}{2}$ in. by the end of the second season. Meanwhile the growth above ground is slow, a maximum height of 3 or 4 in. being attained by the end of the first season; during the second season the growth is not much faster except under favourable conditions, when a height of 1–2 ft. may be reached by the end of the season. Under unfavourable conditions dying back may take place, particularly where drought is severe, the stem of the young plant dying down while the root system develops, and a new stem being produced the following year. The season's growth ceases about November (northern India); some seedlings are leafless by February–March, but others are never quite leafless, the old leaves continuing to fall throughout March. New growth begins in March or April. The seedlings stand a considerable amount of shade, persisting under it for some time. They are hardy against frost and drought, but not against excessive damp, and tend to rot in heavy damp weed-growth. They have great power of struggling through grass, but their development suffers, while more vigorous growth is promoted if the ground is kept clear of weeds and periodically loosened.

SILVICULTURAL CHARACTERS. In the seedling and young pole stage the tree stands moderate shade, but later it requires more light. It is decidedly frost-hardy, and in the abnormal frost of 1905 in northern India it resisted the frost more successfully than almost any other species. It is also drought-resistant; in the abnormal drought of 1907 and 1908 in the forests of Oudh it proved to be conspicuously hardy (*D. tomentosa*), but in the severe drought of 1899–1900 in the Indian Peninsula it was affected to some extent, though sucker reproduction is said to have escaped injury (*D. Melanoxyton*). Young plants and suckers are immune from damage by browsing; in heavily grazed sal forest in Oudh an undergrowth of this species may be found in places where the ground has been grazed bare, while in over-grazed forests in the Peninsula the prevalence of a stunted growth of *Diospyros* is a familiar sight, the development of the tree being probably hindered by the trampling and hardening of the soil and not by browsing.

The tree coppices moderately well, but the coppice-shoots grow slowly; it pollards better, though the growth of the pollard-shoots is also slow. Coppice experiments in North Chanda, (Central Provinces, showed that after April the coppicing power is very poor, the percentage of stools which coppiced successfully in different months being (1) April 100, (2) May 30, (3) August nil. The extensive production of root-suckers, however, is one of the most characteristic features of this tree. Its hardiness and immunity from damage by grazing assist it to establish itself in quantity by this means, and on cleared forest

land masses of sucker reproduction persist for many years after other species have disappeared, and they are difficult to eradicate on land required for cultivation. Similarly on abandoned cultivation sucker growth springs up readily, and if left alone may result in pure crops of *Diospyros*.

NATURAL REPRODUCTION. As already mentioned, the seeds are spread by fruit-bats and by birds, notably hornbills; seedlings may sometimes be found in the forks of trees or in other places above the ground, the seed having been conveyed there by their agency. Under natural conditions, germination begins early in the rainy season and continues during that season; some seed may remain dormant until the second rainy season. Germination is greatly favoured if the seed becomes covered with earth, as in this case the radicle is less liable to destruction by insects, or, if exposed to the sun, by drought. Nevertheless the young taproot is very hardy, and under shade or under the protection of grass it may creep for some distance along the surface of the ground until it is able to penetrate the soil; this is a common habit in natural seedlings. The profusion and tenacity of sucker reproduction is, however, in itself sufficient to ensure the survival and increase of this species even without the aid of seedling reproduction, which is itself often plentiful.

ARTIFICIAL REPRODUCTION. Experiments at Dehra Dun have shown that transplanting from the nursery is attended with much risk owing to the large size of the taproot; this applies both to seedlings transplanted entire and to those transplanted with pruned stem and root. Probably the most successful method, if planting has to be resorted to, would be to sow the seeds in long narrow baskets and to plant these out intact in the second rains. Sowing should be carried out about April-May, care being taken to cover the seeds with earth. Direct sowing is usually preferable to transplanting, the best method being to sow in lines and to keep the lines weeded during the first two or three years. Line sowings with the aid of field crops have been carried out in the Amraoti forest division, Berar.¹

RATE OF GROWTH. The few sample plot measurements available indicate that the rate of growth is slow; these are as follows:

Diospyros Melanoxylon and *D. tomentosa*: rate of growth in high forest sample plots.

Province.	Forest division.	Locality.	Number of years under measurement.	Number of trees under measurement.	Girth classes.	Mean annual girth increment for period.
					ft.	in.
United Provinces	S. Kheri	Kishanpur	9	1	1-2	0.23
Central Provinces	Balaghat	Raigarh and Baihar	8	2	2-3	0.20

A tree felled in West Kurnool, Madras, had 216 rings for a girth of 6 ft., representing a mean annual girth increment of 0.33 in.²

Coppice growth is also slow. Measurements made in 1911 in two coppice coupes each two years old in the Gonda district, United Provinces, gave an average height of 4 and 4.8 ft. as compared with 7.6 and 10 ft. for sal; in

¹ Ind. Forester, xxxvii (1911), p. 8.

² Working Plan for the Gundlabrahmeswaram Range, West Kurnool, H. F. A. Wood, 1912.

either coupe the average number of shoots per stool was 1.4, and the rate of growth of this species was slower than that of any other species present. Measurements in 1912-13 in coppice coupes one year old in Bhandara, Central Provinces, showed an average height of 5.1 ft., as against 7.1 ft. for teak, 3.9 ft. for *Buchanania latifolia*, and 3.8 ft. for *Soymida febrifuga*.

Measurements made in 1910 by Mr. C. M. McCrie in coppice coupes in the Gorakhpur district, United Provinces, gave the following results :

Diospyros tomentosa : rate of growth of coppice, Gorakhpur.

Age. years.	Mean height. ft.	Mean girth. in.	Age. years.	Mean height. ft.	Mean girth. in.
2	4.8	1.8	10	9.1	3.9
4	6.8	2.8	12	9.3	4.1
6	7.9	3.3	14	9.3	4.2
8	8.7	3.6	16	9.3	4.3

2. *Diospyros Embryopteris*, Pers. Vern. *Gáb, kala tendu*, Hind. ; *Timburi*, Mar. ; *Kusharta*, Kan. ; *Niti tumiki*, Tel.

A moderate-sized, much-branched, handsome evergreen tree with a short bole and a dense rounded crown of dark green foliage with shining coriaceous leaves. Bark smooth, dark greenish grey. The fruits are rich in tannin, and the unripe fruits contain a viscid pulp used as gum in bookbinding and for paying the seams of boats. The tree is often planted for ornament in gardens ; it is not a timber tree.

DISTRIBUTION AND HABITAT. The sub-Himalayan tract from the Jumna to the Tista, Chota Nagpur, in many parts of the Indian Peninsula, and in Martaban and Tenasserim. The tree frequents moist and even swampy ground along streams and in shady ravines, where it is sometimes more or less gregarious. In the Dehra Dun valley it is characteristic of swamp forests, in association with *Putranjiva Roxburghii*, *Ficus glomerata*, *Eugenia Jambolana*, *Pterospermum acerifolium*, *Carallia lucida*, *Trewia nudiflora*, *Bischoffia javanica*, and a few other species. In the Sundarbans it is found on old village sites in the interior.

FLOWERING AND FRUITING. In northern India the creamy white fragrant flowers appear from March to May along with the young leaves, which are bright crimson. The fruits begin to ripen about May in the following year, but may be found on the tree for a few months later ; they are more or less globose, 1.5-2 in. in diameter, covered with a red velvety tomentum (Fig. 249, *a*) ; they contain about 5-8 seeds in a glutinous pulp. The seeds (Fig. 249, *b*) are 0.6-0.8 in. by 0.4-0.45 in., compressed, with a fairly thick testa ; about 350-400 weigh 1 lb. The fertility of fresh seed is high, but so far as tests at Dehra Dun show the seed does not retain its vitality for a year. The fruits are eaten by fruit-bats and monkeys, and the seeds are distributed by their agency.

GERMINATION (Fig. 249, *c-g*). Epigeous. The radicle emerges from one end of the seed and descends rapidly, forming a black taproot of some length before the elongation of the hypocotyl is completed. The hypocotyl elongates by arching, and in straightening raises above ground the cotyledons enclosed in the testa and albumen. The cotyledons are caducous, and are usually left

wholly or partially enclosed in the seed-coat, falling with it, or sometimes they extricate themselves, the testa falling to the ground, but they in their turn soon fall, leaving the pointed plumule, from which the first pair of foliage leaves soon expands.

THE SEEDLING (Fig. 249).

Roots : primary root long, thick, terete, tapering, black, at first fleshy, afterwards woody, minutely tomentose ; lateral roots moderate in number, short, fibrous, chiefly in apical part of main root. *Hypocotyl* distinct from root, lower portion 0.5–0.7 in. in length, swollen, grey or light greenish brown, upper portion, 1.5–2.2 in. in length, compressed, pink or green turning dark greenish brown, glabrescent or finely pubescent. *Cotyledons* : petiole 0.1 in. long, channelled above ; lamina 1–1.3 in. by 0.4–0.5 in., foliaceous, oblong lanceolate, entire, glabrous, pale pink, caducous, apices folded into the albumen. *Stem* erect, compressed, pubescent, dark greenish brown, young parts red ; internodes 0.2–0.7 in. long. *Leaves* simple, exstipulate, first one or two pairs opposite or sub-opposite, subsequent leaves alternate or sub-opposite. Petiole 0.1–0.2 in. long, flattened above, minutely pubescent. Lamina 1.5–3 in. by 0.4–0.7 in., oblong lanceolate, entire, dark green, smooth, shining, coriaceous, glabrous above, pubescent on midrib beneath, young leaves red.

The growth of the seedling is very slow, averaging only a few inches a year for the first three years. Seedlings raised at Dehra Dun attained the following maximum heights by the end of the first five seasons : (1) 6 in., (2) 8 in., (3) 10 in., (4) 2 ft. 9 in., (5) 3 ft. 2 in. A long taproot is developed early, and may attain a length of 9 in. within a month of germination ; its subsequent growth is slower, a length of about 18 in. being ordinarily attained by the end of the second season.

In their earlier stages the seedlings are subject to the attacks of insects, while birds, squirrels, and hares bite off the young shoots. Seedlings are sensitive to frost and drought ; they require shade for their best development, and are apt to die off if exposed to a hot sun. They also require plentiful moisture in the soil.

SILVICULTURAL CHARACTERS. The tree is a shade-bearer ; in the natural state young plants develop freely under a fairly heavy canopy. It thrives with abundance of moisture in the soil, and along streams and in swampy ground it is sometimes found growing with its roots submerged in running water ; very moist ground, however, is not essential for its growth, since it is found wild, and is often cultivated, on ordinary loam, where it thrives, provided the soil is not too dry.

NATURAL REPRODUCTION. The seed is frequently spread by animals, particularly monkeys and fruit-bats, and possibly also by birds ; groups of seedlings have been observed in the forks of trees several feet above ground, from seed carried by fruit-bats and passed out in their excreta.

The fruits themselves fall to the ground from about June or July onwards, and soon dry up or rot, the seeds being exposed ; provided the latter become buried within a reasonable time, or are lying in a moist shady place, germination takes place during the rainy season, but seeds lying exposed in the open usually fail to germinate.

ARTIFICIAL REPRODUCTION. Seedlings can be raised in the nursery and transplanted successfully provided care is taken not to injure the long taproot.

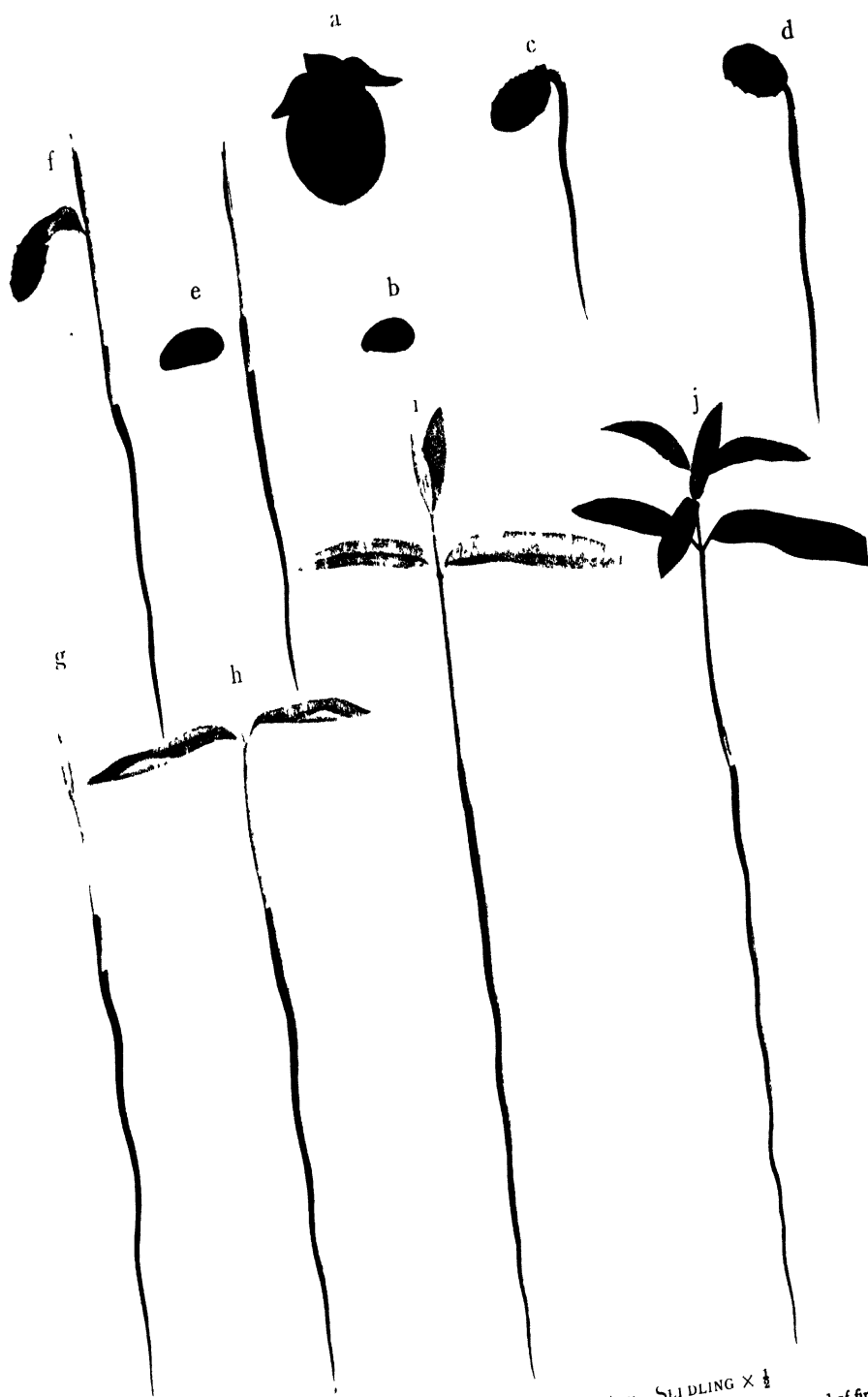


FIG. 249. *Diospyros Embryopteris* SEEDLING $\times \frac{1}{2}$
a—Fruit b—Seed c g—Germination stages h-j Development of seedling to end of first season

Fresh seed should be sown in the seed-beds about July, the seeds being placed about 4 in. apart in drills 9 in. apart. The soil should be well worked up before sowing, and subsequently prevented from caking, and the beds should be shaded and well watered in dry weather. The seedlings usually appear in two to three weeks after sowing. Transplanting may be done either in the first or in the second rainy season ; dry situations exposed to the sun should be avoided, the seedlings being planted if possible under moderate shade, preferably from the side. Watering may be necessary for a time after transplanting. If the trees are grown for their fruit, wide spacing, say 20 ft. by 20 ft. or even more, is necessary owing to the spreading nature of the crowns.

RATE OF GROWTH. The rate of growth is moderate. A cross-section in the silvicultural museum at Dehra Dun had 70 rings for a girth of 3 ft. 3 in., or a mean annual girth increment of 0.56 in. Brandis gives 7–8 rings per inch of radius, representing a mean annual girth increment of 0.78–0.9 in.

3. *Diospyros Kurzii*, Hiern. Andaman marble-wood or zebra-wood. Vern. *Pecha-da*, And. ; *Kala lakri*, Hind. (in Andamans) ; *Thitkyā*, Burm. (in Andamans).

An evergreen tree with thin smooth grey bark, ordinarily attaining a height of 40 to 50 ft. with a clear bole of 15 to 20 ft. and a girth up to 5 ft. ; occasionally it reaches larger dimensions. The wood, which is known on the London market, is a valuable and very handsome variegated ebony with alternating streaks of black and grey ; the out-turn of variegated wood from the log is, however, comparatively small.

The tree is found throughout the Andamans, and occurs also in the Nicobars and Coco Islands. It is found scattered in semi-deciduous and evergreen forests, usually on low-lying and undulating ground, along with padauk (*Pterocarpus dalbergioides*) and its associates. Its silviculture has not been studied in detail.

4. *Diospyros burmanica*, Kurz. Vern. *Tè*, Burm.

A small to moderate-sized deciduous tree with rigid branches. Bark rough, blackish. This tree is common in Burma in *indaing* forest of a dry type, usually on laterite, along with *Dipterocarpus tuberculatus*, *Shorea obtusa*, *Pentacme suavis*, *Buchanania latifolia*, and other trees characteristic of this type of forest, and also in the dry open mixed forests of the dry zone of Burma. The flowers appear in March–April, and the fruits ripen in December–January ; they are 1–1.5 in. in diameter, sweet and edible when ripe. The tree produces root-suckers freely, and often springs up gregariously on abandoned cultivation by means of suckers from roots left in the ground (see Fig. 245).

5. *Diospyros Ebenum*, Koenig. Ebony. Vern. *Karunkāli*, Tam. ; *Tuki*, *nalluti*, Tel. ; *Kaluwara*, Singh.

A large evergreen tree with a dense crown and thick dark coriaceous leaves. Bark dark grey, rather rough, with longitudinal cracks. Mr. A. F. Broun¹ says that in Ceylon it attains a girth up to 14 ft. ; in India it is of comparatively small size. The heartwood furnishes the true ebony of commerce, a jet-black, very hard, close-grained wood, used for turnery, carving, piano-keys, and fine ornamental work of various kinds. The tree is of great commercial importance in Ceylon, whence the wood is regularly exported to

¹ Ind. Forester, xxv (1899), p. 275.

Europe and elsewhere ; in India, however, the trees are neither large nor common enough to be of any great importance commercially.

DISTRIBUTION AND HABITAT. Sparsely scattered in the forests of the Deccan and Carnatic, chiefly in Kurnool and Cuddapah, scarcer farther south. Bourdillon says that in Travancore it has been found only in the Anjinaud valley in the north, but it may also occur on the slopes above Puliyan and near Panagudi. It is a tree of the dry regions, and occurs chiefly in dry ever-green forests.

In Ceylon, according to Mr. Broun, it is most abundant in the dry zone, and the richer forests are all in the northern half of the island, especially in the eastern portion of the North Central Province ; it is also well represented in the Northern and North-Western Provinces. Outside the dry zone it occurs in the intermediate zone, and in the south of the island it penetrates even into the moist zone. The best ebony is found on rocky well-drained soil, usually on sandy loam with a good subsoil drainage, but at times on soil with a fair proportion of clay ; it is frequently found near watercourses which are dry during part of the year, but never on swampy soil. It does not grow pure, but is found scattered in mixture with many other species, including *Chloroxylon Swietenia*, *Mimusops hexandra*, *Nephelium Longana*, *Gleniea zeylanica*, *Vitex altissima*, *Albizzia odoratissima*, *Berrya Ammonilla* (on moister soils), and other species of *Diospyros*.

FLOWERING AND FRUITING. In Ceylon the flowers appear about March, but the flowering season seems to be rather irregular ; the fruits usually ripen before the north-east monsoon, that is, about September–October, but the tree is said occasionally to seed twice a year. Good seed-years are somewhat irregular, and the seed is liable to the attacks of weevils (Broun).

SILVICULTURAL CHARACTERS. The seedlings endure a fair amount of shade, but after they have established themselves the admission of light directly overhead is beneficial. Mr. Broun considers that it is best not to admit too much light until the maximum height is reached, when space should be given for the development of the crown.

RATE OF GROWTH. The rate of growth is slow. Mr. Broun gives for Ceylon the following average figures, which, however, he admits to be only tentative :

Girth.		Corresponding age.
ft.	in.	years.
1	6	25
3	0	75
4	6	135
6	0	200

6. *Diospyros Chloroxylon*, Roxb. Vern. *Ninai*, *nensi*, Mar. ; *Ullingi*, Tel.

A large shrub or small tree, often spinescent. Bark rough, dark grey, with small rectangular corky scales. Wood yellowish grey. This is a useful fuel plant, and yields good fodder ; the fruits are edible. It is found in many parts of central and southern India, extending north to Orissa, Chanda, and Nasik. It is common in dry deciduous forests ; Gamble says it is common in the dry evergreen forests of Cuddapah, Kurnool, North Arcot, and Chingleput, preferring laterite and sandstone hills, and is a useful fuel plant ; Haines says it is common on cotton soil in North and South Chanda.

The flowers appear in June–July, and the fruits ripen from January to April. The fruit is globose, smooth, shining, 0.3 in. in diameter, with 2–3 seeds. The seeds have a high percentage of fertility, and tests at Dehra Dun gave a fertility of 80 per cent. with seeds kept for one year. Experimental plots at Dehra Dun showed that under natural conditions germination starts early in the rainy season, and that, as in the case of *D. Melanoxylon* and *D. montana*, if the seed is not buried, the young taproot may creep along the surface of the ground for some time in its efforts to penetrate the soil. In this case if exposed to the sun the seedling soon perishes, but under shade it may remain alive and vigorous; seedlings with two well developed foliage leaves have been observed with their taproots still creeping along the surface of the ground and developing lateral rootlets, although not yet established in the soil. The seedlings are capable of standing a considerable amount of shade and of persisting under grass; they ordinarily reach a height of 4–6 in. in the first season. The tree produces root-suckers.

7. *Diospyros montana*, Roxb., incl. *D. cordifolia*, Roxb. Vern. *Bistendu*, Hind.; *Tembhurni*, Mar.; *Vakkanai*, Tam.; *Chók*, Burm.

A small to moderate-sized, very variable, deciduous tree, often spinescent. Nowhere very common, but widely distributed in deciduous forests throughout the greater part of India and in Burma (var. *cordifolia* only). The wood does not furnish any black heartwood. The flowers appear from March to June, and the fruits ripen from December to February (northern India), but the fruiting season appears to vary; Bourdillon (Travancore) and Talbot (Bombay) say the rainy season. On three occasions I have received fresh seeds from the Central Provinces in June–July. The fruit is globose or ovoid, 0.7–1.2 in. in diameter, greenish yellow, turning black. The seeds are 0.6–1.1 in. by 0.4–0.5 in., brown, compressed: the percentage of fertility is high.

Under natural conditions the seed germinates early in the rainy season, and if it lies unburied the taproot may crawl along the surface of the ground for some time before it succeeds in penetrating the soil, as in the case of *D. Melanoxylon* and *D. Chloroxylon*. Under these conditions, if exposed to the sun, the germinating seedlings are liable to perish, but under shade they persist for some time until the taproot eventually establishes itself. Grass and weed-growth also act as an efficient protection during germination. The seedlings are capable of standing fairly dense shade. Their growth is slow.

8. *Diospyros ehretioides*, Wall. Vern. *Aukchinsa*, Burm.

A large deciduous tree with spreading branches and large leaves up to 1 ft. or more in length. The wood, which is grey with darker streaks, sometimes handsomely mottled, is not much used. This is a familiar tree in the mixed deciduous forests of Burma, both in the upper and in the lower mixed types, though perhaps commoner in the latter. It is somewhat shade-bearing, its spreading crown being often conspicuous below an upper story. The fruits ripen in the cold season and are eaten by hornbills, as the Burmese name implies.

ORDER XXXVIII. OLEACEAE

Genera 1. FRAXINUS, Linn.; 2. OLEA, Linn.; 3. NYCTANTHES, Linn.; 4. SCHREBERA, Roxb.

1. FRAXINUS, Linn.

Brandis (*Indian Trees*) enumerates five Indian species: (1) *F. floribunda*, Wall., flowers with petals, appearing after the leaves; Afghanistan, trans-Indus, Himalaya, Khasi hills and Shan hills. (2) *F. Griffithii*, Clarke, flowers with petals, appearing after the leaves; Mishmi hills. (3) *F. excelsior*, Linn. (including *F. Hookeri*, Wenzig), flowers without petals, appearing before the leaves, leaflets two to four pairs, base entire, upper part slightly serrate; western Himalaya from the Ravi drainage westwards. (4) *F. oxyphylla*, M. Bieb., similar to (3) but leaflets one to four pairs, coarsely serrate; Baluchistan, Afghanistan. (5) *F. xanthoxyloides*, Wall., syn. *F. Moorcroftiana*, Brandis, a shrub or small tree with very variable leaves, occurring in dry situations in the western Himalaya, Afghanistan, and Baluchistan.

Parker (*Forest Flora for the Punjab*), distinguishing between *F. floribunda*, Wall., and *F. micrantha*, Lingelsh.—a very similar species except that the flowers have no petals—gives (1) *F. floribunda*, Wall., Himalaya, Nepal, Assam, all the western Himalayan species he has seen belong to *F. micrantha* and not to *F. floribunda*. (2) *F. micrantha*, Lingelsh., Himalaya 6,000–7,000 ft., Kumaun to Bashahr and probably farther west; he has, however, seen only one Punjab specimen.

Species 1. *F. floribunda*, Wall.; 2. *F. excelsior*, Linn.; 3. *F. xanthoxyloides*, Wall.

1. **Fraxinus floribunda**, Wall. Indian ash. Vern. *Sum, angu*, W. Him.

A large deciduous tree with opposite imparipinnate leaves; leaflets usually seven to nine, all with petiolules except the upper pair, which are sub-sessile. Branchlets purple, compressed, glabrous, with white lenticels. Bark grey, smooth on young poles, rough with deep longitudinal furrows on older trees. Wood pinkish white, moderately hard, tough, used for oars, shoulder-poles, &c.

It is probable that many specimens termed *F. floribunda* in the forest are in reality *F. micrantha* (see introduction to this genus).

The Indian ash is found in the Himalayan region from Sikkim westwards at 5,000–9,000 ft., in the Khasi hills, and the Shan hills of Upper Burma at 4,000 ft. It is occasionally cultivated in the Himalaya at suitable elevations. In the wild state the tree is by no means abundant, its distribution being somewhat local; it is confined as a rule to rich moist soils and shady situations. Mr. Fernandez¹ says that in the Naini Tal district it occurs generally in the neighbourhood of limestone rocks, and that it seeds profusely and reproduces fairly well on loose soil free from weeds.

The tree is leafless in the winter. The flowers appear in April–May and the fruits ripen in September–October. The seed lies dormant in the ground for a whole year, and transplanting from the nursery is therefore better than direct sowing. Seed may be sown in the nursery in the autumn of ripening

¹ Naini Tal Working Plan.

or in the following spring ; in either case it germinates in the spring about seventeen or twelve months later as the case may be. Transplanting is preferably done in the winter with seedlings kept about two seasons in the nursery. During the first season the growth of the seedling is comparatively slow, but during the second season it is usually faster, a height of 2 ft. being attainable by the end of the season under favourable conditions, while by the end of the third season a height of 3–5 ft. is ordinarily attained. The treatment of the seed usually followed in Europe in the case of *F. excelsior* (see below) may prove suitable for this species.

The growth is slow to moderate : Gamble's specimens gave an average of 13 rings per inch of radius, representing a mean annual girth increment of 0.48 in. Wallich gives 8 rings, or a mean annual girth increment of 0.78 in.

2. *Fraxinus excelsior*, Linn. European ash. Vern. *Súm*, Punjab.

A large straight-stemmed tree. Bark (India) light grey, smooth in young trees, becoming rough with deep longitudinal furrows in old trees. Wood whitish, moderately hard, tough and elastic, used for oars, shafts, tool-handles, and many other purposes. In the European ash there are nine to fifteen leaflets ; the Indian representative has usually five, rarely seven leaflets, and this together with other distinctions led Wenzig to regard it as a distinct species (*F. Hookeri*, Wenzig).

Fraxinus excelsior occurs wild in the western Himalaya at 7,000–10,000 ft. elevation in Hazara, Kashmir, and Chamba. Its distribution is very local ; it is confined to moist, deep, fertile soil, often in the neighbourhood of streams, and attains a height of 80–90 ft. and a girth of 8 ft. and over. There are some good specimens in the upper Siran valley in Hazara, on deep, moist, fertile loam obtained from the decomposition of mica schist ; here the tree grows on the sides of moist ravines, often in the neighbourhood of running water, the surrounding forest consisting of spruce, silver fir, blue pine, and deodar, as well as horse-chestnut, maple, walnut, and other broad-leaved species. Fig. 250 shows a large tree in this locality. Natural reproduction springs up chiefly on newly exposed clean ground on the sides of moist ravines, often among boulders.

The artificial cultivation of this ash deserves more attention. It has been planted with success as low as 4,000 ft., and appears to grow better at lower than at higher elevations. For planting purposes, however, care is necessary always to select deep, moist, fertile soil, preferably on the sides of ravines or near mountain streams.

Based on European experience, its characters and requirements may be briefly indicated. The tree is a light-demander, but stands some shade in youth. It avoids sandy soil, thriving best on deep, moist, fertile loam, and in Europe is found most commonly on low ground near rivers. It has a well-developed root-system, and is wind-firm. It is sensitive to drought and to frost. It coppices and pollards well, and reproduces to some extent by suckers ; stools, however, do not live very long. In Europe the seed ripens in October and falls during the winter, germinating in the second spring : it retains its vitality for two or three years. Before sowing it is usual to bury the seed in sand from the time it ripens until the second spring, when it is sown as late as possible to avoid the risk of late frosts. In nurseries the seedlings are

pricked out in the spring the year after sowing, and are ready for planting out one or two years later.

The ash is treated as coppice, coppice-with-standards, on the pollard system, or as high forest, in which case it should be underplanted with a shade-bearer. The height-growth is fairly rapid, but the tree does not attain a great age or a very large diameter.

3. *Fraxinus xanthoxyloides*, Wall. Syn. *F. Moorcroftiana*, Brandis. Vern. *Sanjal*, *hanúz*, *anga*, W. Him.

A large shrub or small tree with branchlets compressed and minutely and densely pubescent. Bark grey, smooth, dark and cracked when old. Wood hard, used for tool-handles, walking-sticks, and fuel. Indigenous in the western Himalaya from Kashmir to Kumaun at 3,000–9,000 ft., trans-Indus, Afghanistan, and Baluchistan; locally plentiful and often gregarious on dry slopes, chiefly in the inner Himalayan valleys. In Hazara it occurs on dry hill-sides in scrub forest in the Kagan valley, chiefly between 4,500 and 6,000 ft., associated at the lower elevations with *Acacia modesta*, *Olea cuspidata*, *Berberis* spp., and *Punica Granatum*, and in places with *Quercus Ilex*. Fig. 251 shows the rocky ground on which it is often found. The tree is much lopped for fodder. It is an important species in the Baluchistan forests. The flowers appear March–April and the fruit ripens July–August. Adverse weather conditions sometimes prevent the ripening of the seed. The growth is slow: Brandis gives 20 rings per inch of radius, representing a mean annual girth increment of 0.31 in. The following measurements of coppice-shoots in the Hazar-Ganj forest are recorded in the Baluchistan Forest Reports for 1914–15 and 1915–16:

Fraxinus xanthoxyloides: coppice measurements, Hazar-Ganj forest, Baluchistan, 1914–16.

Age.	Height.		Age.	Height.	
	1914–15.	1915–16.		1914–15.	1915–16.
years.	ft.	ft.	years.	ft.	ft.
1	1–3	..	6	4–10	..
2	2–4	2–4	7	6–12	6–12
3	2–6	2–5	8	8–13	8–13
4	2–4	6–8	9	6–14	10–14
5	..	6–9	10	..	10–15

2. OLEA, Linn.

Species 1. *O. cuspidata*, Wall.; 2. *O. glandulifera*, Wall.; 3. *O. dioica*, Roxb.; 4. *O. europaea*, Linn.

1. *Olea cuspidata*, Wall. Syn. *O. ferruginea*, Royle. Indian olive, wild olive. Vern. *Kao*, *kahu*, W. Him.; *Zaitún*, Pushtu. (Fig. 252.)

A moderate-sized unarmed evergreen tree with small coriaceous leaves, dark green above, reddish brown beneath. Bark grey, thin, smooth, exfoliating in narrow strips. Wood brown, very hard, close grained, used for tool-handles, turnery, combs, &c.; an excellent fuel. This species yields very little oil from the fruit kernels, but it makes a suitable stock on which to graft the cultivated olive, *O. europaea*, Linn., to which it is closely allied. It attains a height of 30 to 40 ft. and a girth of 6 ft. or more.

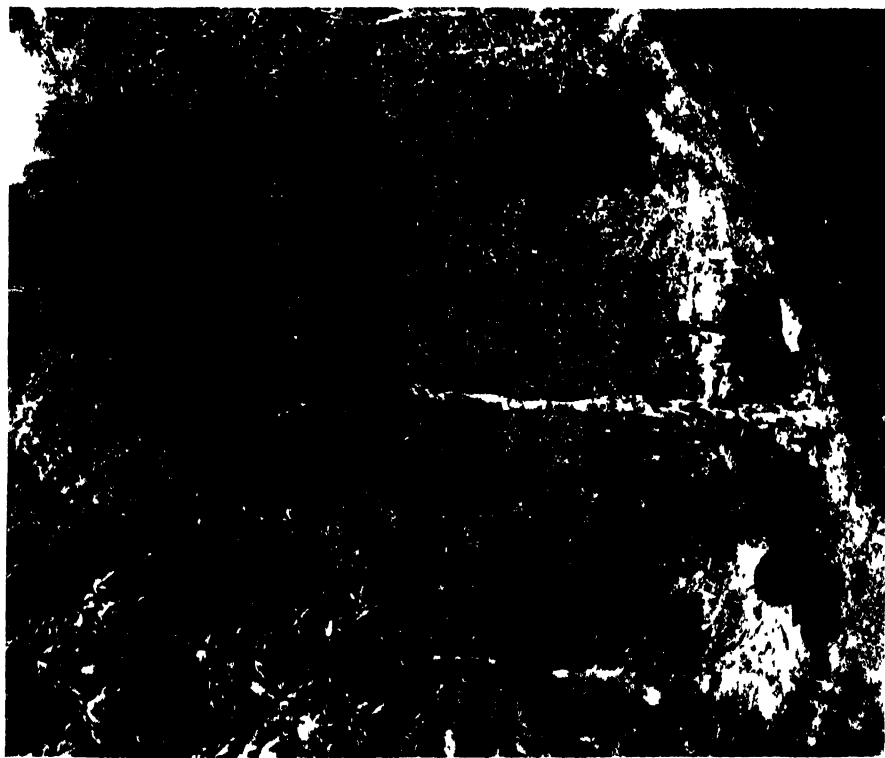


FIG 250. *Fracinus excelsior* (with man at base) girth 8 ft. 1 in.
Upper Siran valley, Hazara.

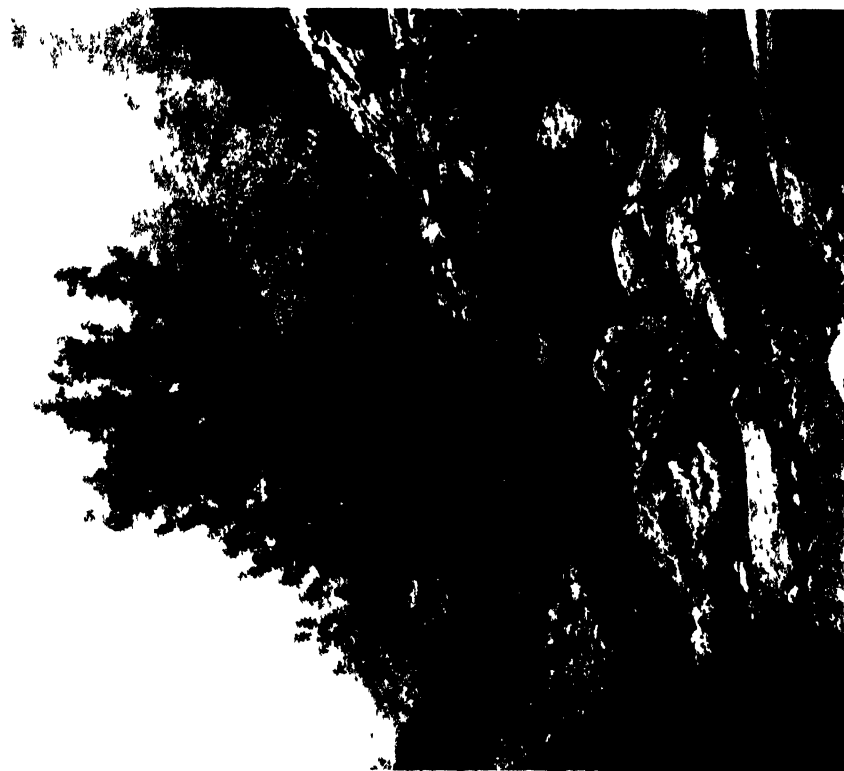


FIG. 251 *Fracinus vaughanholmesii*, Kagan valley, Hazara.



FIG. 252 *Olca cuspidata*, Hazara.

DISTRIBUTION AND HABITAT. Indigenous in the western Himalaya, ascending to 6,000 ft., from the Jumna westward, the Suliman and Salt Ranges, hills to the west of Sind, Afghanistan, and Baluchistan. In the western Himalaya it is somewhat local, occurring chiefly along the outer hills and in the dry inner valleys. In the trans-Indus country, along the eastern flank of the Suliman and other ranges, it is often abundant. In the Salt Range it grows equally well on limestone, sandstone, shale, and marl. It is usually more or less gregarious, and is very common on hilly ground, often associated with *Dodonaea viscosa*, *Acacia modesta*, *A. Catechu*, *Carissa spinarum*, *Reptonia buxifolia*, and *Pistacia integerrima*; in the *Pinus longifolia* forests it often occurs on rocky ground on hot aspects. In the Kalachitta range of hills in the Rawalpindi district it is abundant on limestone, favouring the valleys and the northern slopes up to 1,500–2,000 ft., above which altitude it is gradually replaced by *Dodonaea*: on hot exposed situations with shallow soil it is less plentiful, giving way to *Acacia modesta*. Except in a few places at the foot of this range it does not extend into the plains. In Hazara it is common on the limestone hills of the Khanpur range at 2,500 to 5,000 ft., associated with *Acacia modesta*, *Punica Granatum*, *Berberis Lycium*, *Pinus longifolia*, and other species; in the Kagan valley it is found on hot hill-sides at 3,500–5,500 ft., often with *Fraxinus xanthoxyloides*. It is often planted in gardens in the plains of northern India. The tracts in which the tree grows wild are characterized by great heat and long periods of drought in the hot season, with a considerable degree of cold in the winter; the rainfall for the most part varies from 15 to 30 in.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The leaves are shed in January–February and the new leaves appear before the old ones all fall. The white flowers appear from March to September, according to locality and elevation. The fruit, which ripens from September to December, is a black ovoid drupe about 0.3–0.5 in. long with a bony endocarp.

THE SEEDLING. The growth of the seedling is very slow, an average height of only about 3 in. per annum being the usual rate of growth during the first three years. A long taproot is developed at an early stage. The seedling is sensitive to drought, and under natural conditions requires shade and moderately good soil for its establishment.

SILVICULTURAL CHARACTERS. The tree is a shade-bearer. It is browsed by camels and goats; browsed plants usually assume a dense shrubby form with small leaves, from the centre of which a few long shoots with normal leaves appear, which, if allowed, grow up into trees. Deer and wild sheep (oorial), where present, also do damage by browsing, especially to coppice-shoots. The tree is often lopped for fodder. It coppices well if cut in the dry season, and produces root-suckers. Experiments carried out in the Punjab in 1912 and 1913 showed that from August to October inclusive coppicing was a failure, while from January to June inclusive it was very successful; coppicing in July gave moderately good results, while the results of fellings in November and December were not conclusive when the observations were recorded.¹

NATURAL REPRODUCTION. Mr. B. O. Coventry² has recorded some

¹ Punjab Forest Conference Proceedings, 1913 and 1914.

² Ind. Forester, xli (1915), p. 395.

observations on the natural reproduction of the wild olive. Germination appears to take place about February, and the essential conditions for successful reproduction are shade during youth and sufficient depth of fertile humus soil. Mr. Coventry contrasts the absence of reproduction in the Kalachitta and Khairimurat ranges of the Rawalpindi forest division, where the soil is shallow, exposed, and denuded, with the satisfactory reproduction observable in parts of the Salt Range, where owing to more effective cover and more favourable soil conditions natural seedlings are to be found in some quantity ; these seedlings are always found under the shade of bushes or trees and in pockets of good humus soil, never in the open or on shallow denuded soil. The presence of olive trees in the former tract is accounted for by the fact that these must have sprung up when the ground was well covered with shrubs and trees and the soil had not become denuded, and the perpetuation of the species has been effected by suckers and not by seedling reproduction.

ARTIFICIAL REPRODUCTION. The tree may be grown from seed sown towards the end of the cold season in light porous mould, either in pots or in raised nursery-beds ; the seedlings should be kept shaded and regularly watered. The young plants may be planted out during the rainy season of the following year, or, if irrigation is possible, in April. Direct sowings in blanks always fail, but seed sown in fairly good soil under the shade of bushes may have a reasonable chance of success. The tree can be grown successfully from cuttings, pieces of mature wood about $\frac{1}{2}$ –1 in. in diameter being used : it can also be raised successfully by transplanting root-suckers.

RATE OF GROWTH. The growth is slow. The annual rings are not distinct, but can sometimes be distinguished with approximate accuracy : by their aid and by measurements of coppice-shoots, it is estimated in the Kalachitta working plan that coppice attains a girth of 15 in. in about thirty years, and this period has been adopted as the rotation for coppice fellings. Coppice-shoots six years old in the Dartian reserved forest, Khanpur range, Hazara, reached a height of 11 ft. and a girth of 4 in. at the base. Generally speaking, it may be said that the more vigorous coppice-shoots grow for some years at the rate of about 2 ft. per annum.

2. *Olea glandulifera*, Wall. Vern. *Gulili*, *gair*, *galdu*, W. Him.

A moderate-sized tree with a shady, broad, rounded crown and a short bole. Wood hard, durable. Indigenous in the outer Himalaya, up to 6,000 ft., usually in shady ravines and along rivers and streams ; Mothronwala swamp, Dehra Dun. Gamble's specimens showed 12 to 33 rings per inch of radius, or a mean annual girth increment of 0.19 to 0.52 in., which is slow. Brandis mentions a section of a tree forty-three years old, grown in the Botanic Gardens, Calcutta, which had 43 rings on a radius of 10 in., giving a mean annual girth increment of 1.48 in., which shows that the growth under favourable conditions may be fast.

3. *Olea dioica*, Roxb. Vern. *Karamba*, Mar.

A moderate-sized tree of the eastern Himalaya, Duars, Assam, Chittagong, Western Ghats, southwards to Travancore, in moist forests, both evergreen and deciduous. Bourdillon says that in deciduous forest in Travancore it does not attain more than 50 ft. in height, but in evergreen forest it reaches a height of 100 ft. and a diameter of $2\frac{1}{2}$ ft. He gives the rate of growth as 5 rings per

inch of radius, representing a mean annual girth increment of 1.26 in. The wood is of good quality, but is apparently not used. Fl. January to March ; fr. April to June, S. India (Bourdillon).

4. *Olea europaea*, Linn. European olive, common olive.

A tree closely allied to *O. cuspidata*, but the leaves are grey above and white beneath, the inflorescence is denser, the fruit larger, and the branchlets in the ungrafted plant are spinescent. The olive is indigenous in Syria and is largely cultivated in the Mediterranean region and in certain valleys in the Alps. According to Professor Raoul Blanchard¹ the distribution of the olive in the French Alps depends little on soil, latitude, or altitude, the deciding factor being exposure, for the tree must have shelter from north, north-west, and north-east winds, and will not tolerate any wind-swept situation ; the most favourable aspects in that region are southerly to easterly.

The cultivation of the olive has been attempted from time to time in India, and within recent years experimental cultivation has been carried on with some success in the Punjab by grafting on stocks of *O. cuspidata*. Systematic experiments were started in 1910-11 at Sakesar in the Shahpur district and Khairimurat in the Rawalpindi district, and some of the grafted trees commenced bearing fruit after four years. Experiments have also been carried out in Kashmir and in Baluchistan. In 1910 about 200 olive plants obtained from southern France were planted in Baluchistan, and these fruited in 1916. Budding was carried out on stocks of wild olive (*O. cuspidata*), the latter being cut down to produce coppice-shoots, which were large enough for budding when three years old. It was found that the best time to bud is about September.

3. *NYCTANTHES*, Linn.

Nyctanthes Arbor-tristis, Linn. Vern. *Har*, *harsingar*, *karasli*, *siharu*, Hind. ; *Harsing*, Kan. ; *Parijtak*, Mar. ; *Krishti*, Tel. ; *Seikpalu*, Burm.

A large shrub or small tree with drooping quadrangular branches and scabrous leaves. Bark grey or greenish white, rough. Common in the sub-Himalayan tract, in the Siwalik hills and outer Himalaya up to 5,000 ft., from the Chenab to Nepal, Chota Nagpur, Central India, Central Provinces, southward to the Godavari, Burma (rare). Often cultivated for its fragrant flowers. Within its region this tree, often nothing more than a shrub, is important from its capacity for clothing dry steep hill-sides and rocky ground, where it is often gregarious, forming almost the only vegetation and serving to fix unstable or denuded slopes, where it spreads quickly. It sends out long stout lateral roots from which are produced bushy suckers in abundance : it also reproduces readily from seed. It stands a moderate amount of shade, and is often found as an undergrowth in dry deciduous forests. It is not readily browsed, even by goats, and thus succeeds in establishing itself even where there is grazing. It coppices readily, and gives good fuel. It is leafless in April-May. The fragrant flowers, with orange-red corolla-tubes and white spreading lobes, appear from August to October, and the capsules ripen from November to February.

¹ La Géographie, October and November 1910.

4. SCHREBERA, Roxb.

Schrebera swietenioides, Roxb. Vern. *Mokha*, *ghant*, Hind.; *Mogalinga*, Tam.; *Makkam*, *mokkalapa*, Tel.; *Thitswelwè*, Burm.

A moderate-sized deciduous tree with grey branchlets thickened at the nodes and opposite imparipinnate leaves. Bark grey, thin, scaly. Wood hard, close grained, used for house-posts, turning, &c.

The tree is found in rather dry mixed deciduous forests often on hilly ground, in the sub-Himalayan tract from the Ramganga river eastwards, Chota Nagpur, Central India, Rajputana, the Central Provinces, and the Indian Peninsula generally; Burma, in dry mixed forests. It is not a gregarious tree, but is found scattered in greater or less abundance in mixture with other species.

The tree is leafless from February–March till April–May. The terminal cymose panicles of yellowish brown flowers appear with the young leaves from April to June, and the fruits ripen during the following cold season. The tree is easily recognized from its characteristic fruit, a pear-shaped, two-valved, two-celled, woody capsule about 2–2.5 in. long, with two to four large angular seeds in each cell.

The tree stands a slight amount of shade. In the abnormal drought of 1899 and 1900 in the Indian Peninsula it was only slightly affected, but it is somewhat sensitive to frost. It produces root-suckers.

Little is known regarding the rate of growth: a cross-section 2 ft. 1 in. in girth in the silvicultural museum at Dehra Dun had 31 rings, giving a mean annual girth increment of 0.8 in.

ORDER XXXIX. SALVADORACEAE

SALVADORA, Linn.

Species 1. *S. oleoides*, Dene.; 2. *S. persica*, Linn.

1. *Salvadora oleoides*, Dene. Vern. *Wán*, *ván*, *jál*, Punjab; *Kabbar*, *jhár*, Sind; *Pilu*, Mar.

A shrub or small tree with drooping branches, evergreen or nearly so. Wood sometimes used for building, agricultural implements, &c.; a poor fuel. The sweet fruit is eaten, often dried. The tree is a useful one for clothing desert tracts: it gives a dense shade which is welcomed by cattle in the heat of the day. This is a common species in the arid desert tracts of the Punjab and Sind, and occurs to some extent in Rajputana. In the Jaipur State it is common. It is gregarious, and is frequently associated with *Capparis aphylla*, *Prosopis spicigera*, *Tamarix articulata*, and sometimes with *Salvadora persica*. In the trans-Indus hills it ascends to 3,000 ft., and in the Salt Range to 2,400 ft. (Brandis). It seems to thrive where the rainfall is below 25 in., becoming scarcer where it is higher. It is capable of thriving on saline soils, where, however, it is stunted.

It coppices fairly well, and regenerates freely by root-suckers and to some extent by natural layers. A dense, almost impenetrable growth is often formed by a parent stem surrounded by a ring of root-suckers, while seedlings also spring up under its shade. The new leaves appear about April. The small

greenish white flowers appear in March–April and the fruits ripen about June : the fruit is a yellow berry 0·2 in. in diameter. The seeds are spread by birds, and seedlings may be found under bushes of *Capparis aphylla* or sometimes epiphytically on *Tamarix* and other trees. The tree suffers little from grazing except where it is very heavy ; it is often lopped for camel and goat fodder. It suffers considerably from frost.

2. *Salvadora persica*, Linn. Syn. *S. indica*, Wight ; *S. Wightiana*, Planch. Tooth-brush tree, mustard tree (of Scripture). Vern. *Kabbar*, *pilu*, Sind ; *Jál*, *jhál*, Rajputana ; *Khakhin*, Mar. ; *Ghunja*, Tel. ; *Opa*, Tam.

A small evergreen tree with drooping branches, sometimes attaining 30 to 40 ft. in height, with a short, often fluted stem. The leaves and fruits are pungent. Wood soft, white, little used. A tree of the dry and arid regions of India, with a wider distribution than the last : Baluchistan, Sind, trans-Indus, Punjab, Rajputana, Ganges valley round Delhi and Agra, the Circars, Guzerat, the Konkan, North Kanara, and the Deccan. It is often found on saline soil, and in the Peninsula on black cotton soil. In North Kanara it grows on the sea-coast above high-water mark in thickets with *Clerodendron inerme*, *Zizyphus Oenoplia*, *Z. Jujuba*, and other species (Talbot). In the Thana district it is found along tidal creeks with *Aegiceras* and *Avicennia* (Ryan). It grows readily from seed and coppices well (Brandis). In the Punjab the seed ripens in June. For planting purposes seedlings ought usually to be kept in the nursery for three years. Coppice-shoots in the Abdulla Kheli forest, Baluchistan, measured in 1912–13, reached a height of 16 ft. in five years.

ORDER XL. APOCYNACEAE

This large order contains one or two trees and shrubs of interest in Indian forestry, as well as a large number of climbers, some noxious, some ornamental. Most of the species have milky juice, and some are producers of caoutchouc. Attention was drawn some years ago to the possibilities as a rubber-producing plant of the Burmese climber *Urceola esculenta*, Benth. (syn. *Chavannesia esculenta*, DC.), but experiments have shown that the quantity of rubber yielded does not pay for the labour of obtaining it. *Chonemorpha macrophylla*, G. Don, a widely distributed climber of the moist forests of India, yields a form of caoutchouc, but is not exploited. *Parameria glandulifera*, Benth. (vern. *Talaingsók*, Burm.), a large climber of the coasts of Tenasserim and the Andamans, is said to yield caoutchouc of good quality. Of non-Indian rubber-producing plants the best known are species of *Landolphia* and *Kickxia* and *Funtumia elastica*, Stapf.

Among familiar climbers of the forest and waste lands may be mentioned *Vallis Heynei*, Spreng., and *Ichnocarpus frutescens*, R. Br. A strikingly handsome climber, which is frequently grown in gardens, and produces masses of large bell-shaped flowers, is *Baumontia grandiflora*, Wall., a native of the eastern Himalaya, Sylhet, and Chittagong. It grows rapidly and is easily propagated from seed, cuttings, or layers.

Genera 1. *HOLARRHENA*, R. Br. ; 2. *ALSTONIA*, R. Br. ; 3. *WRIGHTIA*, R. Br. ; 4. *CARISSA*, Linn.

1. HOLARRHENA, R. Brown.

Holarrhena antidysenterica, Wall. Syn. *H. Codaga*, G. Don ; *Chone-morpha antidysenterica*, G. Don. Vern. *Dudhi*, *karra*, *kura*, *kachri*, Hind. ; *Kuda*, Mar. ; *Kodaga*, Mar. ; *Lettôkgyi*, Burm. (Fig. 253.)

A small deciduous tree with opposite entire leaves. Bark greyish brown, scaly. Wood white, soft, even grained, used for carving into picture-frames, domestic utensils, and fancy articles of various kinds. The bark and seeds (*indarjau*, Hind.) are used medicinally. The tree is of interest and importance in Indian forestry from its great abundance and wide distribution, in which respect it is a useful accessory species in clothing the ground and acting as a nurse to more valuable species : the tree is important for reclothing waste lands.

DISTRIBUTION AND HABITAT. Widely distributed throughout India and Burma in deciduous forests and open waste lands, where it is often gregarious. It ascends the outer Himalayan valleys to 4,000 ft., and is abundant in the sal and mixed deciduous forests of the sub-Himalayan tract, being one of the component species of the mixed type of forest representing the transition stage between the riverain forests of *Acacia Catechu* and *Dalbergia Sissoo* and the sal forests on older and more elevated land. It is also a common species in the mixed deciduous forest of the dry *bhabar* tract skirting the base of the outer hills. It is common throughout the greater part of the Indian Peninsula, down to Malabar and Travancore.

In Burma it is fairly common in dry open mixed forests, often on laterite, and in *indaing* (dry dipterocarp) forest. It reaches the dry zone of Burma, but is probably absent from the drier parts of that zone.

Within its habitat the absolute maximum shade temperature varies from 105° to 118° F., the absolute minimum from 30° to 55° F., and the normal rainfall from 30 to 150 in.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The leaves turn yellow about December-January and fall about January-February, the tree remaining leafless until the new leaves appear about April. The flowering period is somewhat variable : flowering may commence as early as April, but usually takes place in May and June, sometimes continuing until July and August, when flowers may be found along with nearly full-sized unripe fruits. The white flowers, which are arranged in terminal corymbose cymes, are very fragrant. The fruits are pairs of slender follicles 8-16 in. long : they develop rapidly after the flowering is over, and are full-sized by August to October, but do not ripen until February to April, when they dehisce on the tree, and the numerous seeds escape. The seeds (Fig. 255, *a*) are 0.5-0.8 in. long, linear, light brown, with a thin, somewhat brittle, closely adhering testa, and crowned at one end with a coma of pale brown silky hairs 1.5-2 in. long, with the aid of which the seeds are distributed to some distance by the wind : 900-1,000 seeds weigh 1 oz., and there are usually about 25-30 in each follicle. Fresh seed has a high percentage of germination, but a considerable proportion loses its vitality if kept for one year.

Flowering and fruiting begin at an early stage in the life of the tree. A nursery-raised seedling at Dehra Dun, from seed sown in May 1911, flowered

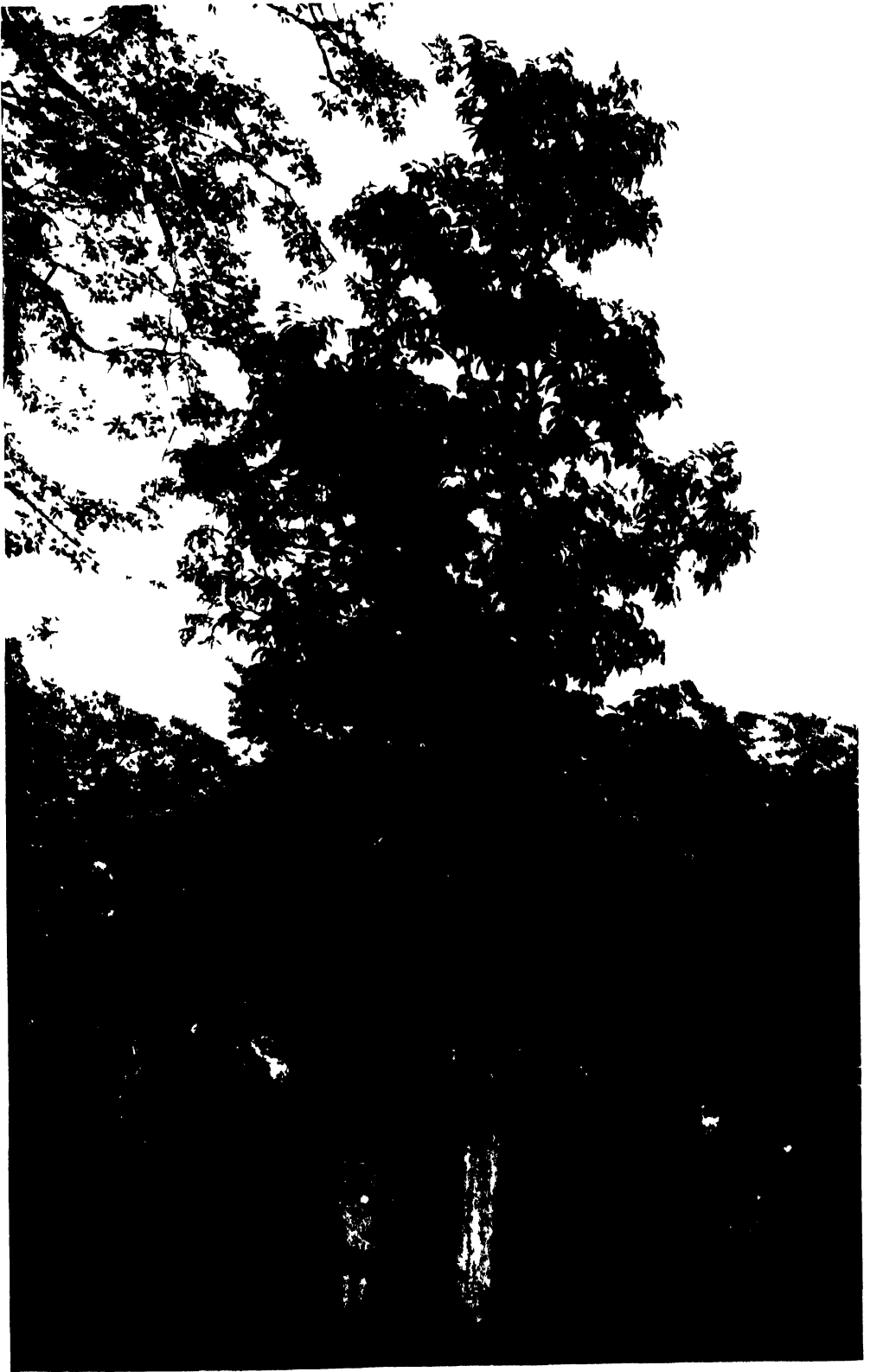


FIG 253. *Holarrhena antidysenterica* in fruit, Dehra Dun, United Provinces.



FIG 254 *Alstonia scholaris*, Dehra Dun, United Provinces.

for the first time in May 1913 and bore numbers of good fruits in February-March 1914. Under natural conditions, where the plants do not develop so vigorously, flowering does not take place so early, as has been observed in the case of plants grown under natural conditions at Dehra Dun; in the forest, however, plants still in the condition of shrubs may often be observed in flower.

GERMINATION (Fig. 255, b-f). Epigeous. The radicle emerges from the end of the seed: the hypocotyl arches slightly, soon straightening and carrying above ground the cotyledons with the testa usually enclosing their extremities. The cotyledons, which are convolute in the seed, unroll themselves and expand, and the testa then falls to the ground, often adhering for some time to one of them before falling.

THE SEEDLING (Fig. 255).

Roots: primary root moderately long, terete, tapering, wiry, white turning yellow or light brown, pubescent: lateral roots numerous, moderately long, fibrous, pubescent, distributed down main root. **Hypocotyl** distinct from root, 1.2-2 in. long, terete, tapering upwards, white turning green, minutely pubescent. **Cotyledons**: petiole less than 0.1 in. long, channelled above, pubescent: lamina 0.9-1.1 in. by 0.5-0.7 in., foliaceous, cordate, acute, entire, bright green, glabrous, or slightly pubescent near the base on the under side, convolute in the seed, 5-veined from the base, the three central veins more prominent than the two lateral veins, subsidiary veins reticulate. **Stem** erect, terete, woody, pubescent; internodes 0.5-1.3 in. long. **Leaves** simple, opposite, exstipulate. Petiole 0.15 in. long, channelled above. Lamina 1.7-3.5 in. by 0.6-1.3 in., ovate lanceolate, acute or acuminate, base acute and slightly decurrent, entire, glabrous, lateral veins 6-9 pairs.

Under natural conditions the seedling grows somewhat slowly during the first season, as a rule reaching a height of about 4 to 6 in. by the end of the year; in subsequent years the growth is more rapid. Weeding and watering greatly stimulate growth. Seedlings are frost-tender and are also liable to be killed by drought during the first season, mortality from the latter cause being considerable. Young plants are fairly light-demanding, and suffer from suppression: they are sometimes liable to serious defoliation by caterpillars. The leaves of seedlings fall from December to February, new growth commencing in March (northern India).

The following measurements in experimental plots at Dehra Dun give some indication of the rate of growth of young plants under different conditions:

Holarrhena antidysenterica: development of seedlings, Dehra Dun.

Condition under which grown.	Height at end of season.			
	1st season.	2nd season.	3rd season.	4th season.
1) Nursery plant, weeded and watered	1 ft. 5 in.	6 ft. 6 in.	10 ft. 5 in.	13 ft. 0 in.
2) Transplants of first rains, not weeded or watered after transplanting	Maximum 1 ft. 6 in.	Maximum 3 ft. 2 in.	1 ft. 9 in.—4 ft. 0 in.	..
3) Broadcast sowing, weeded, not watered	„ 0 ft. 5 in.	„ 1 ft. 2 in.	Maximum 3 ft. 9 in.	..
4) Line sowings, weeded, not watered	„ 0 ft. 7 in.	„ 1 ft. 6 in.	..	..
5) Natural conditions (among weeds)	„ 0 ft. 4½ in.	„ 1 ft. 7 in.	1 ft. 10 in.	5 ft. 5 in.



FIG. 255. *Holarrhena antidysenterica*. Seedling $\times \frac{5}{8}$
 a, seed (without coma); b-f, germination stages; g-i, development of seedling to end of first season.

SILVICULTURAL CHARACTERS. The tree stands a slight amount of shade, but develops best in full light. In the abnormal drought of 1907 and 1908 in the forests of Oudh it proved to be decidedly hardy. It is sensitive to frost, but has good powers of recovery from the base when killed down, and may often be found in abundance persisting on grassy areas subject to severe frost. It is not readily browsed, even by goats. It coppices well, and shoots up readily after severe damage by fire. It produces root-suckers in abundance.

NATURAL REPRODUCTION. Under natural conditions germination takes place during the rainy season, chiefly at the beginning of that season. In their earlier stages many seedlings are destroyed by drought, and frost often keeps the young growth back. Nevertheless this species regenerates with great freedom, owing partly to its regular and abundant seeding from an early age, partly to its comparative immunity from damage by grazing, and partly to its power of recovery from injury of all kinds. In the open grass-lands so common in sal forests it often appears in great abundance with fire-protection, and is a most useful nurse for the sal seedlings, which appear underneath it and gradually make their way through it.

ARTIFICIAL REPRODUCTION. The tree can be raised artificially without difficulty both by direct sowing and by transplanting from the nursery. Experiments at Dehra Dun have shown that great success can be attained by line sowings along with field crops, provided that a strip about 2 ft. wide is kept clear of field crops along the line, the crops being sown in the intervening spaces; regular weeding along the lines is necessary during the first two or three years, and loosening of the soil from time to time is advantageous; as the seedlings are apt to form a dense line they should be thinned out periodically.

For transplanting purposes seed should be sown in the nursery in March or early April: the seedlings ordinarily appear in two or three weeks, and are ready for transplanting in the first rainy season.

RATE OF GROWTH. High forest sample plots in the United Provinces show mean annual girth increments of 0.05, 0.12, 0.13, 0.14, 0.28, and 0.41 in., but these figures are probably misleading, as they refer chiefly to small-sized trees in sal sample plots, and have evidently been thoroughly suppressed, in the first four instances at all events. A cross-section from the United Provinces in the silvicultural museum at Dehra Dun had 60 rings for a girth of 3 ft. 6 in., giving a mean annual girth increment of 0.7 in. Gamble's specimens showed 7 to 8 rings per inch of radius, giving a mean annual girth increment of 0.78 to 0.9 in.

Various coppice measurements have been recorded. Measurements made in 1911 in Gonda, United Provinces, gave an average height of 5.1 ft. as against 4.7 ft. for sal in a coupe one year old, and 6.8 and 5 ft. as against 10 and 7.6 ft. for sal in two coupes two years old. Measurements by Mr. A. F. Broun in 1886 in a coppice coupe nine years old near Dehra Dun gave an average height of 15.5 ft. as against 16 ft. for sal, and an average girth of 8 in. as against 8.6 in. for sal.

Measurements made in 1910 by Mr. C. M. McCrie in coppice coupes in the Gorakhpur district, United Provinces, gave the following results for *Holarrhena* as compared with sal:

Holarrhena antidysenterica : measurements in coppice coupes, Gorakhpur.

Mean height.			Mean girth.		Mean height.			Mean girth.	
Age.	<i>Holarrhena.</i>	Sal.	<i>Holarrhena.</i>	Sal.	Age.	<i>Holarrhena.</i>	Sal.	<i>Holarrhena.</i>	Sal.
years.	ft.	ft.	in.	in.	years.	ft.	ft.	in.	in.
2	4.0	3.0	..	..	10	12.0	15.3	3.7	4.8
4	6.5	7.0	1.7	2.0	12	13.6	17.5	4.3	5.8
6	8.5	10.3	2.5	2.9	14	15.2	19.2	4.8	6.7
8	10.4	13.0	3.2	3.8	16	16.8	20.9	5.3	7.5

2. ALSTONIA, R. Br.

Alstonia scholaris, R. Br. Vern. *Satni*, *satian*, Hind.; *Satwin*, Mar.; *Mudhol*, Kan.; *Eda kula*, Tel.; *Palai*, Tam.; *Lettók*, *taungmèók*, Burm. (Fig. 254.)

A large evergreen tree with a tall stem, often fluted and buttressed, whorled branches, and dark green shiny leaves in whorls of 4 to 10. Bark grey, yellow inside, exuding milky juice when cut. Wood soft, white, used for boxes, scabbards, writing-boards, &c.

Scattered throughout the greater part of India and Burma where the rainfall is over 50 in., preferring fairly moist situations; not in the dry regions. The tree is nowhere very abundant or gregarious. Fl. December to March; fr. May to July. The fruits consist of pairs of slender follicles 1–2 ft. long, hanging in clusters, containing numerous densely ciliate seeds.

The only measurement of the rate of growth available is one made in Gorakhpur, United Provinces, showing an average height of 6 ft. 8 in. for coppice three years old.

3. WRIGHTIA, R. Br.

Species 1. *W. tomentosa*, Roem. and Sch.; 2. *W. tinctoria*, R. Br.

1. *Wrightia tomentosa*, Roem. and Sch. Syn. *W. mollissima*, Wall.; *W. Wallichii*, A. DC. Vern. *Dudhi*, *keor*, *darbela*, Hind.; *Kala indarjau*, Mar.; *Tella pala*, Tel.; *Pala*, Tam.; *Lettókthein*, Burm.

A small deciduous tree with slender pubescent branches and opposite distichous softly tomentose leaves. Bark grey, corky, exuding a yellowish white latex when cut. Wood white, moderately hard, even-grained, used for turning, carving, domestic utensils, &c.

DISTRIBUTION AND HABITAT. Distributed throughout the greater part of India and found in various parts of Burma, but not so common or so gregarious as *Holarrhena antidysenterica*. In the sub-Himalayan tract it is rare west of the Beas; it ascends the outer valleys to 4,000 ft., and extends eastward to Assam. It is common on the boulder deposits of the dry *bhabar* formation skirting the base of the outer hills. In Chota Nagpur and the Central Provinces it is somewhat local and nowhere abundant, and throughout the Peninsula generally it is distributed more or less locally. It occurs commonly in rather open mixed deciduous forests, and also in sal forest. In Burma it is fairly common in mixed deciduous forests of the upper and lower types.

Within its habitat the absolute maximum shade temperature varies from 105° to 118° F., the absolute minimum from 30° to 55° F., and the normal rainfall from 35 to 150 in.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The leaves fall during January and early February, and the trees are leafless during February, March, and part of April, the new leaves appearing in April-May. The yellowish white flowers, with red coronal scales, in corymbose cymes, appear from April to June. The fruit consists of two connate many-seeded follicles joined into a single pendulous grooved cylindrical pod 6-12 in. long and 0.5-0.7 in. thick, rough with white specks; the follicles separate before dehiscing. The fruits are usually full-sized by August, but do not ripen and dehisce until from January to March or even April. The seeds (Fig. 256, *a*) are 0.5-0.7 in. long, linear, light yellowish grey, crowned with a tuft of white silky hairs by the aid of which they are disseminated by the wind: about 1,500-1,700 seeds weigh 1 oz. Fresh seeds have a high percentage of fertility, but if kept for a year they lose their vitality.

GERMINATION (Fig. 256, *b-e*). Epigeous. The radicle emerges from the end of the seed and the hypocotyl elongates, carrying above ground the cotyledons enclosed in the testa. The cotyledons, which are convolute in the seed, unroll themselves and expand, and the testa then falls to the ground, or clings to the edge of one cotyledon for some little time before falling.

THE SEEDLING (Fig. 256).

Roots: primary long, terete, wiry, flexuose: lateral roots numerous, fibrous, distributed down main root. *Hypocotyl* distinct from root, terete, tapering slightly upwards, finely pubescent. *Cotyledons*: petiole 0.1 in. long, flattened above, finely pubescent: lamina 0.6-0.8 in. by 0.5-0.7 in., foliaceous, slightly fleshy, cordate, acute, entire, green, glabrous above, minutely pubescent beneath, convolute in the seed. *Stem* erect, terete, tomentose; internodes 0.4-0.8 in. long. *Leaves* on main stem opposite, sub-opposite or alternate, exstipulate. Petiole up to 0.1 in. long, finely tomentose. Lamina 0.8-2.5 in. by 0.5-0.8 in., ovate- or elliptical-lanceolate, acuminate, entire, finely tomentose on both surfaces, lateral veins 5-10 pairs.

Under natural conditions the growth of the seedling during the first season is moderate, a height of about 3-10 in. being attained: subsequently the growth is more rapid provided it is not interfered with by weeds, which exercise an adverse influence on the development of the young plant. Weeding and watering stimulate rapid growth from the commencement, seedlings regularly weeded and watered at Dehra Dun having reached a height of as much as 3 ft. 5 in. to 3 ft. 10 in. by the end of the first season. These vigorous plants, whose further growth is recorded below, produced flowers, from which no fruits developed, at the end of the second season, while at the end of the third season flowers were produced which resulted in the formation of fertile fruits.

The seedlings are decidedly sensitive to frost, but though liable to be killed back they have good power of recovery. In northern India the season's growth ceases about October-November, new growth starting in March-April; the leaves commence falling in October-November and the seedlings are leafless from December to March.

The following measurements in experimental plots at Dehra Dun give some indication of the rate of growth of young plants and the beneficial effect of weeding:



FIG. 256. *Wrightia tomentosa*. Seedling $\times \frac{1}{4}$.
 a, seed (without ooma); b-e, germination stages; f-h, development of seedling during first season.

Wrightia tomentosa : development of seedlings, Dehra Dun.

Condition under which grown.	Height at end of season.			
	1st season.	2nd season.	3rd season.	4th season.
Transplants, not weeded or watered	Maximum 0 ft. 11 in.	0 ft. 9 in.-2 ft. 0 in.	1 ft. 2 in.-2 ft. 8 in.	..
Broadcast sowings, not weeded or watered	0 ft. 2 in.-0 ft. 4 in.	Maximum 0 ft. 7 in.	Maximum 1 ft. 9 in.	..
		(Growth much impeded by grass and weeds)		
Broadcast sowings, weeded or not watered	Maximum 0 ft. 11 in.	Maximum 2 ft. 10 in.	0 ft. 5 in.-6 ft. 0 in.	..
		(Seedlings crowded, the larger suppressing the smaller)		
Nursery sowings, regularly weeded and watered	3 ft. 5 in.-3 ft. 10 in.	8 ft. 6 in.-9 ft. 0 in.	12 ft. 5 in.-12 ft. 9 in.	Maximum 15 ft. 0 in.

SILVICULTURAL CHARACTERS. The tree is a moderate light-demander, and is often found as an undergrowth species in open deciduous forest. In the abnormal drought of 1907 and 1908 in the forests of Oudh it proved to be fairly hardy, though not so hardy as *Holarrhena*. It coppices well, and has good power of recovery from injury. It is somewhat frost-tender.

NATURAL REPRODUCTION. Under natural conditions germination takes place at different times during the rainy season. Some mortality occurs among seedlings owing to drought during breaks in the rains. Reproduction is most plentiful on clear loose ground free from weed-growth.

ARTIFICIAL REPRODUCTION. Weeded line sowings carried out as in the case of *Holarrhena* give good results. For transplanting purposes seed should be sown in the nursery about March or April: the seedlings ordinarily appear above ground in three to four weeks, and may be transplanted during the first rainy season, but care is necessary during transplanting, otherwise they are liable to die back or to be killed outright.

RATE OF GROWTH. A cross-section in the silvicultural museum at Dehra Dun had 31 rings for a girth of 2 ft. 5 in., giving a mean annual girth increment of 0.94 in. Gamble's specimens gave an average of 8 rings per inch of radius, or a mean annual girth increment of 0.78 in. Measurements of one tree extending over a period of nine years in the Kishanpur working circle, South Kheri, United Provinces, gave a mean annual girth increment of 0.4 in. for the period.

2. *Wrightia tinctoria*, R. Br. Vern. *Khirmi*, *dudhi*, Hind.; *Kala kuda*, Mar.; *Vepala*, Kan.; *Tedlapal*, *repala*, Tel.; *Nila palei*, Tam.

A small deciduous tree of the Indian Peninsula, extending northward to Rajputana and Banda. This is a common tree in the Deccan in open deciduous forests, often on trap; it extends southward in considerable abundance to Travancore, and is found most commonly on dry sandy soil and on hilly ground. It is also found in Burma. The new leaves and white flowers appear from March to June and the fruit ripens in January-February. The fruit consists of a pair of slender follicles cohering at the tips only. The tree stands moderate shade, and is often found as an undergrowth species in deciduous forests. It produces root-suckers. The growth is slow to moderate. A cross-section in the silvicultural museum at Dehra Dun had 24 rings for a girth of 11 in., giving a mean annual girth increment of 0.46 in. Gamble's specimens gave 7 rings per inch of radius, or a mean annual girth increment of 0.9 in.

4. *CARISSA*, Linn.

Species 1. *C. spinarum*, A. DC.; 2. *C. Carandas*, Linn.

1. *Carissa spinarum*, A. DC. Syn. *C. diffusa*, Roxb. Vern. *Karaunda*, Hind.; *Kavali*, Kan.; *Kalivi*, Tel.; *Kan*, Burm.

An evergreen shrub with green branchlets and pairs of divaricate thorns at the nodes. The wood is hard and close grained, and is used for turning, combs, &c. The leaves have shown promise as a tanning material. This gregarious shrub is common in the drier forest tracts throughout India, ascending the outer Himalaya to 4,000 ft. It is common in the scrub forests of the dry zone of Burma. It springs up readily not only in open places but also as an undergrowth species, and is useful for clothing dry rocky ground. Although readily browsed by sheep and goats it persists in a remarkable manner; bovine animals do not appear to be so partial to it. In some of the heavily grazed tracts of Oudh it forms a dense undergrowth, developing into a small tree high enough to enable cattle to wander underneath. In such places it is almost the only species which survives the heavy grazing and the trampling of the soil; its dense shade kills out the grass and ruins the grazing.

The small white star-like flowers appear in the hot season, from April to June; they are extremely fragrant, especially in the evening. The fruits ripen in the cold season; they are dark purple, edible, sweetish juicy berries, and are readily eaten by birds, which scatter the seeds. Under natural conditions the seeds germinate during the rainy season; with abnormal rain some may germinate as early as March, but in this case the seedlings usually die of drought in the subsequent hot weather. The seedlings have good power of penetrating grass and weed-growth, but succumb to excessive damp.

The growth of the seedling is slow, a height of about 2 to 3 in. being attained in the first season, about 6 to 8 in. in the second season, and about 10 to 13 in. in the third season.

The shrub coppices well and produces root-suckers freely; its power of spreading by root-suckers no doubt accounts in part for its persistence in spite of heavy grazing. It is frost-hardy, and in the abnormal drought of 1907 and 1908 in the forests of Oudh it proved decidedly drought-resistant. It stands moderate shade. The growth is somewhat slow; coppice-shoots ten years old near Dehra Dun had an average height and girth of 8 ft. and 2 in. respectively. Gamble's specimens showed 8 to 15 rings per inch of radius, giving a mean annual girth increment of 0.42 to 0.78 in.

2. *Carissa Carandas*, Linn. Vern. *Karaunda*, Hind.

This species resembles *C. spinarum*, but is usually a larger shrub or a small tree with larger leaves and fruits. It is frequently cultivated.

ORDER XLI. ASCLEPIADACEAE

This order is of interest mainly as containing a number of forest climbers, a few of some importance as fibre plants and several noxious to tree-growth. Among the best known are *Cryptolepis Buchanani*, Roem. and Sch., a very common climber which in some forest tracts gives a good deal of trouble; *Dregea volubilis*, Benth., a very troublesome climber in the riverain forests of

Acacia Catechu and *Dalbergia Sissoo* in some parts of the sub-Himalayan tract (see Fig. 122), *Marsdenia Roylei*, Wight, and *M. tenacissima*, W. and A., which yield strong silky white fibres. The seeds of species of this order are scattered by wind, as they are usually winged and crowned with a dense coma.

Genera 1. CRYPTOSTEGIA, R. Br.; 2. CALOTROPIS, R. Br.

1. CRYPTOSTEGIA, R. Br.

Cryptostegia grandiflora, R. Br.

A large climber, probably a native of Madagascar, often cultivated or run wild in India. It yields a fairly good quality of caoutchouc, and for some years past attempts have been made to cultivate it in the outer hills of the Punjab: although it has been found to grow tolerably well it suffers from excess both of heat and of cold, the young shoots dying off, though new shoots are again sent out. It grows well in pure sand in Jaipur, Rajputana, with a rainfall of about 20 in., and is recommended for planting shifting sands on the plains: transplanting should be carried out during the rainy season when the ground has been soaked with rain.

2. CALOTROPIS, R. Br.

Species 1. *C. gigantea*, R. Br.; 2. *C. procera*, R. Br.

1. *Calotropis gigantea*, R. Br., and 2. *Calotropis procera*, R. Br.

Well-known and widely distributed shrubs with milky juice and leaves covered beneath with a white felty tomentum. They furnish useful fibres from the stem, and the hair of the seeds is used for stuffing cushions. Owing to their silky coma the seeds are carried to a considerable distance by the wind, and the plants spring up readily on open ground and waste places. *C. procera* in particular springs up in abundance on new sandy or gravelly alluvium in the beds of rivers and is a common forerunner of riverain forests of *Acacia Catechu* and *Dalbergia Sissoo*. The flowers and fruits appear at various times, but chiefly in the cold and hot seasons.

ORDER XLII. LOGANIACEAE

Genera 1. STRYCHNOS, Linn.; 2. FAGRAEA, Thunb.

1. STRYCHNOS, Linn.

Species 1. *S. Nux-vomica*, Linn.; 2. *S. Nux-blanda*, A. W. Hill; 3. *S. potatorum*, Linn. f.

1. *Strychnos Nux-vomica*, Linn. Strychnine, nux-vomica or snakewood tree. Vern. *Kuchla*, *kajra*, Hind.; *Kar*, Mar.; *Kasarkana*, Kan.; *Mushti* Tel.; *Yetti*, Tam.

A moderate-sized or large handsome evergreen or deciduous tree with opposite smooth shining leaves five-nerved from the base, the three central nerves being prominent. Bark yellowish grey to blackish grey, thin, smooth, covered with minute tubercles and containing chlorophyll tissue. The seeds of this tree are the nux-vomica of commerce, and are of importance in yielding the alkaloids strychnine and brucine. They are largely collected for sale;

fresh clean silvery seeds collected from the ripe fruits command a higher price than the dull-coloured seeds collected off the ground.

DISTRIBUTION AND HABITAT. The Indian Peninsula northward to the Circars, Orissa, Raipur, South Chanda, and the Konkan. Common in southern India. Occasional in Chota Nagpur, but always near villages, and probably not indigenous (Haines). Gorakhpur forests in the United Provinces (Brandis). Dry region of Ceylon.

In the Indian Peninsula it is common in many localities in deciduous forests, usually of a moist type. Talbot says that in Bombay it is very common in the moist monsoon forests of the Konkan and North Kanara, and abundant on laterite along the sea-coast in evergreen thorn scrub. In the Central Provinces it occurs chiefly on deep alluvial soils in South Chanda and on the quartzite plateau of the Laun range, Raipur (Haines).

Within its habitat the absolute maximum shade temperature varies from 96° to 118° F., the absolute minimum from 40° to 65° F., and the normal rainfall from 35 to 150 in. or more.

LEAF-SHEDDING, FLOWERING, AND FRUITING. In moist types of forest the tree is evergreen, but in dry types, for example on laterite, it loses its leaves for a short time in the hot season. The small greenish white flowers appear from March to May, and the fruits ripen in the cold and hot seasons from December to June. The fruit is a berry about the size and colour of a small orange, with a rather hard coriaceous pericarp and a bitter white pulp in which are a number of nearly circular flat seeds.

The seeds are poisonous, but the pulp and even the seeds are eaten by langur monkeys. Gamble says: 'The pulp of the fruit, though containing also some poison, is eaten by the langur monkeys (*Semnopithecus entellus*, Blyth, and *S. priamus*, And.) and also by the Malabar pied hornbill (*Anthracoceros coronatus*, Elliot), and perhaps by other hornbills, parrots, and other birds, but the seeds are probably always rejected or else passed undigested. But while the langur monkeys can apparently eat the fruit and even the seeds without harm, other monkeys, as well as other animals and man, cannot do so, though it is said that the flying fox can eat the pulp with impunity.'

SILVICULTURAL CHARACTERS. The tree is a shade-bearer, growing under a moderate canopy even in semi-evergreen types of forest. It produces root-suckers. It is immune from damage by browsing, as animals avoid it.

RATE OF GROWTH. Little is known regarding the rate of growth. A cross-section in the silvicultural museum at Dehra Dun had 31 rings for a girth of 2 ft. 3 in., giving a mean annual girth increment of 0.87 in.

2. *Strychnos Nux-blanda*, A. W. Hill. Burmese strychnine tree. Vern. *Kabaung*, Burm.

A moderate-sized evergreen or deciduous tree with opposite smooth shining leaves five-nerved from the base, the three central nerves being prominent. Bark yellowish grey to blackish grey, often fluted.

DISTRIBUTION AND HABITAT. Burma, common in the upper and lower mixed deciduous forests, and often very plentiful in moist semi-evergreen forest as a lower story beneath *Dipterocarpus alatus* and other tall trees. It is also common in *indaing* (dry dipterocarp) forest on laterite, though here

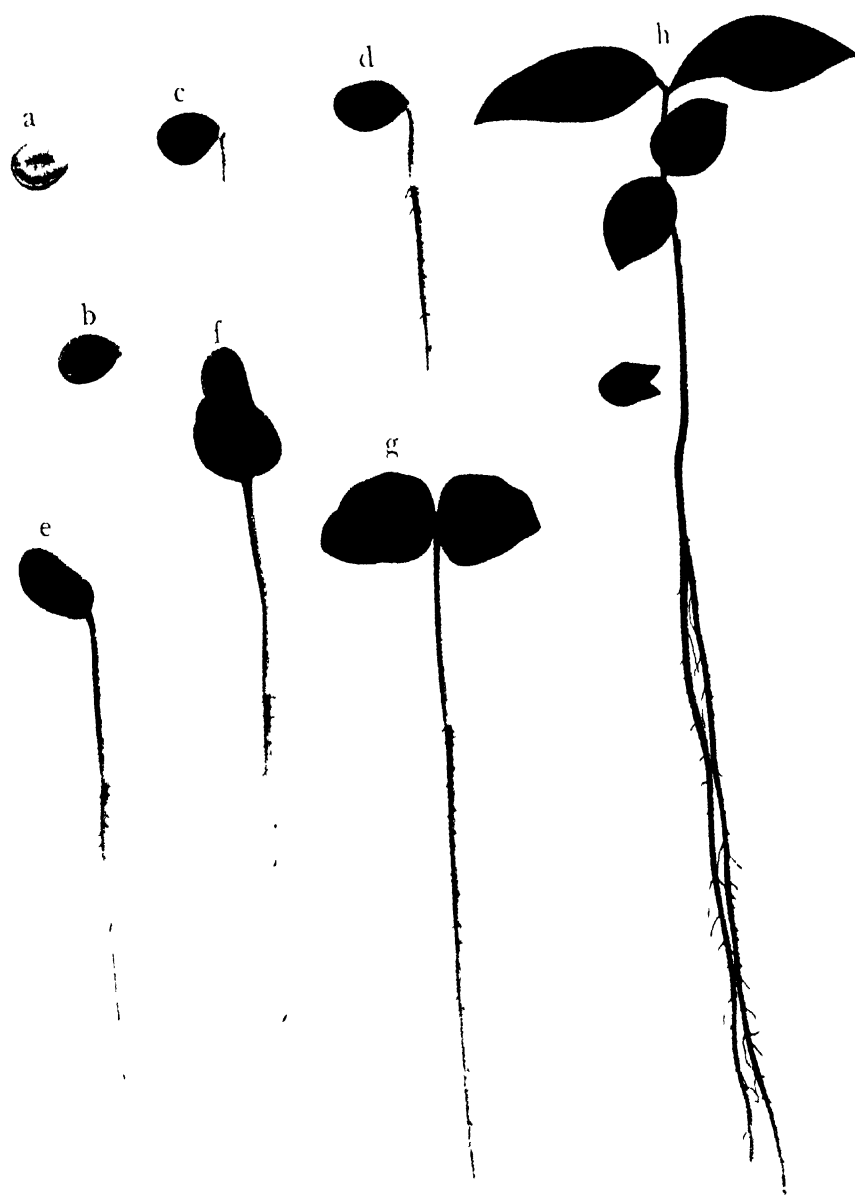


FIG. 257. *Strychnos Nux-blanda* SEEDLING $\times \frac{1}{2}$
a Seed b - g Germination stages h Seedling early in second season

it is usually a small tree. It enters the dry zone of Burma, but is not found in the driest parts.

LEAF-SHEDDING, FLOWERING, AND FRUITING. As a rule the tree loses its leaves for a short time in the hot season, though in moist localities it is ever-green. The small greenish white flowers appear in April-May and the fruits ripen in the cold season. The fruit is a berry about the size of a small orange, with a rather hard coriaceous orange-coloured pericarp and a whitish pulp in which are a number of seeds. The seeds (Fig. 257, *a*) are 0.6-1 in. by 0.5-0.8 in., nearly circular, flat, light yellowish grey with a satiny lustre and a soft felty testa; about 250-350 weigh 1 lb. The seeds retain their vitality to some extent for a year; in a test carried out at Dchra Dun 50 per cent. of seeds kept for one year germinated. As a rule the tree fruits well every year.

GERMINATION (Fig. 257, *b-g*). Epigeous. The radicle emerges from one end of the seed and descends rapidly, forming a thick yellowish white taproot. The hypocotyl subsequently elongates with little or no arching, carrying above ground the cotyledons enclosed in the testa, within which is a layer of albumen. The testa is pushed towards the tips of the cotyledons with their expansion, and usually adheres to the apex of one of them for some little time before finally dropping to the ground.

THE SEEDLING (Fig. 257).

Roots: primary root long, thick, terete, only slightly tapering, yellowish white or light brown, at first delicate in texture, afterwards woody; lateral roots moderate in number to numerous, short, fibrous, distributed down main root. *Hypocotyl* distinct from root, 2.2-3 in. long, terete, tapering slightly upwards, green, glabrous. *Cotyledons* sessile, 1.5-2.7 in. by 1.3-2.5 in., foliaceous, broadly ovate, acute or slightly acuminate, entire, green, glabrous, shining, prominently 5-veined from the base. *Stem* erect, terete or slightly compressed, green, glabrous. *Leaves* simple, opposite. Petiole about 0.1 in. long. Lamina, first pair 1.2-1.5 in. by 1-1.3 in., broadly elliptical, acute, base rounded, entire, dark green, glabrous, shining; subsequent leaves 3-3.5 in. by 1.4-1.7 in., elliptical, acuminate, base acute, dark green, glabrous, shining, prominently 3-veined from the base, with an additional pair of intra-marginal veins.

During the first season the growth of the seedling above ground is slow, development being confined to little or nothing more than the expansion of the large green leafy cotyledons: a long rather thick taproot of somewhat delicate texture is rapidly formed, and may reach a length of 8 or 9 in. within a month of germination. During the second season the growth of the seedling is more rapid. Seedlings are extremely sensitive to cold, and cannot exist if there is frost.

SILVICULTURAL CHARACTERS. The tree is a shade-bearer, growing up under a moderate canopy in deciduous and even in moist semi-evergreen forest. It is sensitive to cold, and does not grow in localities subject to frost.

NATURAL REPRODUCTION. The seed germinates readily with heat and moisture, and natural reproduction is often abundant, its establishment being aided by the immunity of the young plants from damage by browsing. The factors influencing natural reproduction require further study.

ARTIFICIAL REPRODUCTION. Owing to the length and delicacy of the young taproot transplanting requires great care, and the best method of

carrying it out is to sow the seeds singly in long baskets or bamboo tubes and to transplant these bodily during the second rainy season. The young plants should be raised in free porous soil and should be kept under moderate shade while in the nursery.

3. *Strychnos potatorum*, Linn. f. Clearing-nut tree. Vern. *Nirmali*, Hind.; *Nivali*, Mar.; *Chili-gidda*, Kan.; *Chilla*, Tel.; *Tettancottai*, Tam.

A small to moderate-sized deciduous (or evergreen?) tree with a fluted stem, opposite coriaceous shining leaves, and lenticillate branchlets swollen at the nodes. Bark thick, blackish, corky, with deep vertical cracks. Unlike *S. Nux-vomica* this tree is not poisonous; the seeds are used to clear muddy water by rubbing the insides of vessels with them, and the pulp of the fruit is eaten. The wood is hard, close-grained, yellowish grey when seasoned, with conspicuous white markings, used for carts, shafts, agricultural implements, &c.

The tree is common in many of the dry deciduous forests of the Indian Peninsula. It is a shade-bearer, growing up well under the canopy of deciduous forest. It is drought-resistant, having remained unaffected in the severe drought of 1899–1900 in the Indian Peninsula. It produces root-suckers. The small white fragrant flowers, in axillary cymes, appear from February to May, and the fruits ripen from October to March. The fruit is a sub-globose berry 0.5–0.75 in. in diameter with a firm pericarp, black when ripe, with one or two seeds 0.4–0.5 in. in diameter in a whitish pulp. The seedling, like that of *S. Nux-vomica*, has a soft whitish delicate taproot.

2. FAGRAEA, Thunb.

Glabrous evergreen trees or shrubs, sometimes scandent, often epiphytic: seven known Indian species.

Fagraea fragrans, Roxb. Vern. *Anan*, Burm.

A moderate-sized handsome evergreen tree, usually less than 6 ft. in girth; bark 0.2–0.5 in. thick, grey to brown, with deep longitudinal cracks. Wood light brown, hard, very durable, said to withstand teredo, used for bridge and wharf piles, building, &c. Apart from the value of its timber the tree is useful for afforesting low-lying grassy tracts, and its handsome appearance makes it well suited as an ornamental shade tree.

The tree is very common in *indaing* (dry dipterocarp) forests of Tenasserim from Moulmein southwards, being particularly abundant in the Heinze basin of South Tenasserim, where there are said to be 200,000 tons available in lengths up to 60 ft.¹ It is found in the Andamans, and is common in the Malay Peninsula (vern. *Ternbusu*), where Mr. A. M. Burn-Murdoch² notes regarding it: 'The tree is widely distributed and will grow well in open places and even in *lalang* grass, being seldom met with in big forests. It grows easily from seed and is a fast grower. It is especially plentiful in parts of the Kuala Pilah district, also in Province Wellesley and Malacca, while there is an almost pure forest of this species on the east coast of Pahang, north of Kuantan near Baloh. There is a large plantation at Kuala Lumpur.' Mr. H. C. Hill³

¹ Ind. Forester, xxv (1899), p. 440.

² Trees and Timbers of the Malay Peninsula, Part II, p. 3.

³ Reports on Forest Conservancy in the Straits Settlements and Federated Malay States, 1900.

says that in the Malay Peninsula it is very largely gregarious, coming up freely on grassy blanks and being easily propagated.

The fruit, a red berry about the size of a pea, ripens in Tenasserim about September–October. The seeds are minute.

ORDER XLIII. BORAGINACEAE

Genera 1. *CORDIA*, Linn.; 2. *EHRETIA*, Linn.

1. *CORDIA*, Linn.

This genus comprises about fifteen Indian trees and shrubs, some with very ornamental wood suitable for cabinet work. Some of these species deserve more study than they have yet received.

Species 1. *C. Myxa*, Linn.; 2. *C. vestita*, Hook. f. and Thoms.; 3. *C. Rothii*, Roem. and Sch.; 4. *C. Macleodii*, Hook. f. and Thoms.

1. *Cordia Myxa*, Linn. Syn. *C. obliqua*, Willd. Vern. *Lasora*, *bhokar*, *borlu*, Hind.; *Buhal*, *bohari*, Beng.; *Bhokar*, *shelu*, Mar.; *Challe*, Kan.; *Iriki*, Tel.; *Vidi*, Tam.; *Thanat*, Burm.

A small or moderate-sized deciduous tree with variable orbicular, elliptical, oblong, or obovate coriaceous glabrous leaves, and often drooping branches. Bark greyish brown, smooth or longitudinally wrinkled. Wood moderately hard, not durable, used for boat-building, well-curbs, gun-stocks, &c.; a good fuel. The bast fibre is used for cordage. The leaves are used in Burma for cheroot-wrappers, and the tree is frequently grown round Burmese villages and pollarded for the production of leaves. Its mucilaginous fruits are eaten.

DISTRIBUTION AND HABITAT. Throughout India, Burma, and Ceylon, ascending in Himalayan valleys to 5,000 ft. It is not a gregarious tree, but is widely distributed, preferring moist shady ravines and the sides of valleys. It is found in a great variety of localities, from the dry forests of Sind and Rajputana to the moist deciduous forests of Burma and western India, and is often cultivated. In Burma it enters the tidal forests (Kurz). Within its habitat in India the absolute maximum shade temperature varies from 95° to 120° F., the absolute minimum from under 30° to over 60° F., and the normal rainfall from under 10 in. to 120 in. or more, though in the driest regions it exists by the aid of river water.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The tree is leafless for a short time in the hot season. The small white polygamous flowers in loose corymbose cymes appear from March to May. The fruits ripen from June to August, some remaining on the tree through September (northern India). The fruit is a yellow or pinkish yellow shiny globose or ovoid drupe 0.5–1 in. long seated on the saucer-like enlarged calyx, and containing a hard one- or two-celled stone (Fig. 258, *a*) in a viscid edible pulp: the fruits turn black on ripening. About 120–160 stones weigh 1 oz. The trees are a striking sight when covered with the yellow fruits, which are eagerly eaten by monkeys and birds. Bourdillon (Travancore) says the fruits ripen from February to May, and Kurz (Burma) says March to April.

So far as tests carried out at Dehra Dun show, the seed has a rather low percentage of fertility, possibly owing to the fact that the stones are often

bored into and the seed destroyed by insects. It retains its vitality to some extent if kept for a year.

GERMINATION (Fig. 258, *b-f*). Epigeous, resembling that of *Tectona grandis* and *Gmelina arborea*. The fruit-stone opens by the splitting off of one or two valves on the side, according to the number of cells and seeds, and one or two seedlings may appear from one stone. The radicle emerges through the crack thus formed, and the hypocotyl elongates with or without arching, raising above ground the very characteristic fan-like plicate cotyledons, which quickly unfold; the fragments of the fruit-stone remain on or under the ground.

THE SEEDLING (Fig. 258).

Roots: primary root moderately long, becoming thick and tough in second season, terete, tapering; lateral roots numerous, moderately long, fibrous. **Hypocotyl** distinct from root, 0.4–0.9 in. long, terete or slightly compressed, cylindrical or tapering slightly upwards, green, pubescent. **Cotyledons**: petiole 0.1–0.2 in. long, flattened above, pubescent; lamina 0.4–0.6 in. by 0.6–1 in., foliaceous, reniform or sub-orbicular, broader than long, crenate, green, glabrous, palmately 5-veined, the veins prominently branched in radiate form, the branches terminating in the hollows between the crenatures, plicate along the veins, the folds persisting in fan-like form when the cotyledons expand. **Stem** erect, terete, pubescent. **Leaves** simple, alternate, exstipulate: petiole up to 0.2 in. long; lamina 0.8–5 in. by 0.4–4 in., elliptical or obovate, acute, mucronate, base acute, serrate, glabrous or sometimes slightly pubescent near the base on the under surface.

The growth of the seedling during the first season is slow, a height of 2–4 in. being attained by the end of the season even under favourable conditions. In the second season the growth is much faster; plants raised in the nursery at Dehra Dun and regularly weeded and watered attained a height of 4½ ft. by the end of the second season. The young plant has a decidedly branching habit. Regular weeding and watering have a marked effect on development. Young plants are frost-hardy, but if exposed to a hot sun they are apt to die of drought under natural conditions.

SILVICULTURAL CHARACTERS. The tree stands moderate shade. In some localities in which it occurs it stands frost well, but in the Changa Manga plantation it suffers badly. In the abnormal drought of 1907 and 1908 in the forests of Oudh it proved to be decidedly drought-resistant. It coppices and pollards well, and has good power of recovery from injury.

NATURAL REPRODUCTION. Although the fruit does not ripen until the early part of the rainy season the seeds germinate during the rainy season in which they fall. Many, however, lie ungerminated, and of these a considerable proportion are destroyed by insects, which bore through the fruit-stones and eat the seeds. A certain number lie apparently in good condition until the following rainy season, but whether or not they germinate then has not been determined. As already mentioned, the seeds are disseminated by monkeys and birds, but many fruits fall around the trees; the fleshy portion soon rots off and germinating seedlings, with their characteristic plicate cotyledons, may often be found during the rainy season. These seedlings, however, will be found to die off through drought after the rains unless they are in a comparatively moist and shady situation.



FIG. 258. *Cordia Myxa*. Seedling, $\frac{1}{1}$.
 a, fruit stone ; b-f, germination stages ; g, h, early development of seedling.

ARTIFICIAL REPRODUCTION. The fruit-stones should be sown in the nursery when the fruit ripens, about June–July, covered with earth and regularly watered. The seedlings begin to appear in about three to four weeks, but may continue to appear for three or four months : they should be regularly weeded and watered, and will be ready for transplanting during the following rainy season. Transplanting does not give much trouble, but it is preferable to prune down the stem to about 1 in. from ground-level and to trim off the roots to a small extent.

RATE OF GROWTH. The annual rings are sometimes but not always distinct. A cross-section in the silvicultural museum at Dehra Dun showed 51 rings for a girth of 3 ft. 9 in., representing a mean annual girth increment of 0.88 in. Brandis gives 3 to 9 rings per inch of radius, representing a mean annual girth increment of 0.7 to 2.1 in. Of specimens examined by Gamble only two showed distinct rings, of which there were 1 to 2 per inch of radius, representing a mean annual girth increment of 3.14 to 6.28 in., which is extremely fast.

The following measurements in coppice coupes at Bullawala near Dehra Dun, recorded by Mr. A. F. Broun in 1886, show the rate of growth of *Cordia* as compared with sal coppice :

Cordia Myxa : coppice measurements, Bullawala, Dehra Dun.

Age. years.	Mean height.		Mean girth.*	
	<i>Cordia Myxa</i> . ft.	Sal. ft.	<i>Cordia Myxa</i> . in.	Sal. in.
8	12.5	16.2	7.2	8.3
9	13	16	12	8.6
9	13.8	13.5	10.4	8.7
10	20	11.9	24	5.9

2. *Cordia vestita*, Hook. f. and Thoms. Vern. *Kumbi, kum, kum-paiman, bairola, latora*, Hind.

A small deciduous tree with rough coriaceous leaves and a somewhat crooked bole. Bark greenish grey, smooth, with occasional deep widely separated longitudinal cracks, exfoliating in large woody scales. Wood hard, brown, streaked or mottled, very handsome, and suitable for ornamental furniture.

DISTRIBUTION AND HABITAT. Sub-Himalayan tract from the Jhelum to the Sarda, rather scattered and nowhere very common. It is often found on somewhat dry hill-sides in mixed deciduous forest, as in the Siwalik hills and the outer Himalaya, where it ascends to 4,000 ft. It is also met with on open grass-lands and in sal forest.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The tree is leafless for a short time in the early part of the hot season, the new leaves appearing about April–May. The small yellowish white flowers appear from February to April and the fruits ripen in June–July. The fruit is a yellow fleshy pointed drupe about 0.5–0.7 in. long, resting in the enlarged saucer-like calyx. The pulp is sweetish and edible ; it is eaten by birds, which scatter the hard fruit-stones (Fig. 259, *a*). About 80–90 fruit-stones weigh 1 oz. Fresh seed tested at Dehra Dun gave 50 per cent. of fertility, and seed from the same sample kept for a year gave 43 per cent.



FIG. 259. *Cordia alliodora*. SEEDLING $\times \frac{1}{2}$.

a. Fruit stone, showing valve. b, c. Germination stages. f, i. Development of seedling during first season.

GERMINATION (Fig. 259, b-e). Epigeous, resembling that of *C. Myxa*. The putamen splits open by the opening of a valve on one side of the stone, and through the crack thus formed the radicle descends and the characteristic fan-like plicate cotyledons, on long stalks, push their way upwards; the segments of the putamen remain in or on the ground, or one piece is carried above ground over the folded cotyledons, falling to the ground with their expansion. The young shoot subsequently appears from between the long cotyledonary petioles.

THE SEEDLING (Fig. 259).

Roots : primary root long, thick, terete, tapering, minutely tomentose : lateral roots moderate in number and length, fibrous, minutely tomentose. **Hypocotyl** distinct from root, 0.1-0.2 in. long, thick, white or green, glabrous. **Cotyledons** : petiole 0.8-1.5 in. long, flattened above, sparsely covered with minute hairs : lamina 0.7-0.9 in. by 0.9-1.5 in., foliaceous, reniform or sub-orbicular with a retuse base, broader than long, crenate, green, scabrous above, glabrous beneath, palmately 5-veined, the veins prominently branched in radiate form, the branches terminating in the hollows between the crenatures, plicate along the veins, the folds persisting in fan-like form when the cotyledons expand. **Stem** erect, terete, stiff, greenish, pubescent : internodes 0.4-1.2 in. long. **Leaves** simple, alternate, exstipulate. Petiole 0.25-0.35 in. long, channelled above, pubescent. Lamina 1.4-7 by 0.6-5 in., ovate acuminate, base acute or obtuse, serrate, dentate or entire, coriaceous, scabrous above, pubescent beneath.

The growth of the seedling during the first season is slow to moderate, but under favourable conditions it is fairly rapid in subsequent seasons. Weeding and loosening of the soil have a marked influence on the growth, which is much retarded by the presence of weeds ; watering has less effect than weeding. The following measurements have been recorded in the case of seedlings raised under different conditions at Dehra Dun :

Cordia vestita : development of seedlings, Dehra Dun.

Situation under which grown.	Height at end of season.			
	1st season.	2nd season.	3rd season.	4th season.
In nursery ; weeded and watered	3-9 in.	3-5 ft.	..	..
Transplants of first season at subsequently weeded	Maximum 7 in.	Maximum 10½ in.	1 ft. 5 in.-1 ft. 7 in.	..
broadcast sowings, weeded and not watered	Maximum 4½ in.	Maximum 4 ft. 6 in.	6-12 ft.	Maximum 14 ft. 6 in. (girth 7 in.)

Seedlings produce a taproot which is often long and stout, a length of as much as 20 in. having been measured at the end of the first season. The season's growth ceases about November. The seedlings are leafless during January-February, and new growth starts in the end of February or during March. Seedlings are sensitive to frost, and are often killed back, but have excellent powers of recovery. They are somewhat sensitive to drought. They stand moderate shade, and even require it in a dry hot situation.

SILVICULTURAL CHARACTERS. The tree is a moderate shade-bearer. Although the seedlings are sensitive to frost the tree is hardy, and may be found persisting on grassy blanks subject to rather severe frosts where only a limited number of species are capable of surviving. It coppices well.

NATURAL REPRODUCTION. Under natural conditions the seed begins to germinate as a rule in August, and continues germinating throughout the rainy season. A certain proportion remains dormant for a year, germinating in the second rainy season. Seed which has become buried germinates much more readily than that which is lying on the surface of the ground ; the latter usually fails to germinate at all. In dry soil exposed to the sun the seedlings tend to die of drought in the dry season, and a certain amount of shade is necessary for their establishment.

ARTIFICIAL REPRODUCTION. The seed should be sown in the nursery in June or July, covered with soil and watered. The seedlings ordinarily begin to appear above ground in about two weeks, and may be transplanted during the first rainy season when about 3 to 4 in. high, though it is preferable to keep them in the nursery until the second rains, sheltering them from frost during the winter. They should be regularly weeded, the soil being kept loose ; watering should be done sparingly or not at all, but in dry hot weather shading is beneficial. When transplanting is done early in the second rainy season the size of the plants may necessitate the trimming down of the roots to some extent ; in this case either the branches should be pruned off or the whole plant should be pruned down to within about 2 in. from ground-level.

3. *Cordia Rothii*, Roem. and Sch. Vern. *Liar*, Sind ; *Gondi*, *gundi*, Hind.

A small tree of the dry parts of north-west, central, and southern India, chiefly in Rajputana, Sind, and the Deccan. The wood is hard, brown, handsomely streaked, and suitable for ornamental work. Growth, according to Gamble, 10 rings per inch of radius, giving a mean annual girth increment of 0.63 in.

4. *Cordia Macleodii*, Hook. f. and Thoms. Vern. *Dhaiman*, *dhagan*, Hind. ; *Dhaiwan*, Mar. ; *Hadang*, Kan. ; *Godela*, Ajmer.

A moderate-sized tree of the Indian Peninsula, Rajputana, Central India, Chota Nagpur, and Orissa, in dry deciduous forests. This tree also has a handsome wood suitable for cabinet work.

2. EHRETIA, Linn.

Species 1. *E. laevis*, Roxb. ; 2. *E. acuminata*, R. Br.

1. *Ehretia laevis*, Roxb. Syn. *E. floribunda*, Benth. ; *E. aspera*, Roxb. Vern. *Chamror*, *koda*, Hind. ; *Datrang*, Mar. ; *Adak*, Kan. ; *Pogadi*, Tel. ; *Addula*, Tam. ; *Gyaungbyu*, Burm.

A moderate-sized deciduous tree with an irregularly-shaped stem and smooth light grey to whitish bark, yellow and soft inside. Wood tough, used for agricultural implements, but as a rule little used except for fuel.

This tree is common throughout the greater part of India in deciduous forests, extending into dry regions such as Sind, the trans-Indus hills, and Rajputana. It is very common in sal forests. It occurs also in Burma.

The tree is leafless during part of February–March. The masses of small white flowers appear from February to April, and the bunches of orange-red berries, sometimes covering the tree, appear from March to June. Both in flower and in fruit the trees are a conspicuous sight.

The tree stands moderate shade. It is somewhat frost-tender, but in the

abnormal drought of 1907 and 1908 in the forests of Oudh it proved to be decidedly drought-resistant. It coppices well and produces root-suckers.

The rate of growth is slow to moderate. Measurements in sal forest sample plots in the Siwalik forest division, United Provinces, showed mean annual girth increments of 0.01, 0.07, 0.30, 0.39, and 0.57 in. Some of these obviously refer to suppressed trees. A cross-section in the silvicultural museum at Dehra Dun showed 31 rings for a girth of 2 ft. 9 in., giving a mean annual girth increment of 1.06 in. Gamble's specimens showed 5 to 8 rings per inch of radius, representing a mean annual girth increment of 0.78 to 1.26 in.

Measurements made by Mr. C. M. McCrie in 1910 in coppice coupes in the Gorakhpur district, United Provinces, showed the following results for *Ehretia laevis* as compared with sal :

Ehretia laevis : coppice measurements, Gorakhpur.

Age. years.	Mean height.		Mean girth.	
	<i>Ehretia</i> . ft.	Sal. ft.	<i>Ehretia</i> . in.	Sal. in.
2	2.5	3	1.8	2.0
4	5.4	7	2.7	2.9
6	8.1	10.3	3.6	3.8
8	10.6	13	4.5	4.8
10	12.7	15.3	5.4	5.8
12	14.6	17.5	6.3	6.7
14	16.5	19.2	7.2	7.5
16	18.2	20.9		

2. *Ehretia acuminata*, R.Br. Syn. *E. serrata*, Roxb. Vern. *Puna*, *punia*, Hind.; *Bual*, Ass.; *Petthin*, Burm.

A moderate-sized deciduous tree with grey longitudinally fissured bark. Wood moderately hard, used for building, agricultural implements, gun-stocks, &c. The leaves, plucked when quite young, are used for mixing with tea to make the brick-tea exported from China to Tibet, where the warmth combined with the rich red liquor produced by these leaves is said to be appreciated by the Tibetans.

The tree is local, though fairly common, in parts of the sub-Himalayan tract and outer Himalayan valleys, ascending to 5,000 ft. ; it occurs also in the Duars, Assam, Khasi and Chittagong hills, and Burma. In the sub-Himalayan tract it is often found on boulder formations and on grass-lands.

The tree is leafless in December–January, the new leaves appearing in February–March. The fragrant white flowers, in conical terminal panicles, appear in March–April, and the fruit, a small drupe, ripens in November–December.

The growth is moderate. A cross-section in the silvicultural museum at Dehra Dun showed 53 rings for a girth of 4 ft. 6 in., giving a mean annual girth increment of 1.02 in. One specimen examined by Gamble showed 7 rings per inch of radius, giving a mean annual girth increment of 0.9 in.

ORDER XLIV. BIGNONIACEAE

An order containing nine Indian genera of trees, shrubs, and climbers, many of which are remarkable for their handsome flowers; in addition there are several exotic species cultivated for ornament. The order contains some forest trees of interest yielding fair timbers. Several of the species are remarkable for the profusion with which they send up root-suckers.

Genera 1. STEREOSPERMUM, Cham.; 2. OROXYLUM, Vent.; 3. MILLINGTONIA, Linn. f.; 4. TECOMA, Juss.

1. STEREOSPERMUM, Cham.

This genus contains seven Indian species, a few of which are of some importance as accessory species. They are characterized, among other features, by their long, more or less cylindrical capsules containing a thick corky dissepiment filling up most of the capsule, along which are arranged the numerous winged seeds. The various species require further study silviculturally. The production of root-suckers appears to be a general characteristic.

Species 1. *S. suaveolens*, DC.; 2. *S. chelonoides*, DC.; 3. *S. xylocarpum*, Benth. and Hook. f.; 4. *S. neuranthum*, Kurz.

1. *Stereospermum suaveolens*, DC. Syn. *Bignonia suaveolens*, Roxb. Vern. *Padal*, *pandri*, Hind.; *Parul*, Mar.; *Kywèmagyolein*, Burm.

A large deciduous tree with large opposite imparipinnate leaves 1-2 ft. in length. Bark grey, exfoliating in large flat scales. Wood hard with a small yellowish brown handsomely mottled heartwood. The tree is a common and important accessory species, particularly in sal forest. It is a useful tree for reclothing bare hill-sides, as may be seen in the Siwalik hills, and for restocking grassy blanks subject to frost.

DISTRIBUTION AND HABITAT. This tree is found throughout the greater part of India in mixed deciduous and sal forests. It is common in the sub-Himalayan tract, ascending the outer hills to 4,000 ft., but is rare west of the Jumna. It occurs also in Rajputana, Chota Nagpur, Central India, and in many other parts of the Indian Peninsula, chiefly in valleys and on plateaux and plains. It is found in Upper and Lower Burma, and according to Kurz is not infrequent in the *indaing* forests of Martaban. It is probably much commoner in the sub-Himalayan tract than elsewhere, and is a constant companion of the sal; it often tends to become gregarious on clayey ground, but is by no means confined to such soil and is often found in abundance on sandy and gravelly soils. It is frequently found on grassy savannah lands. In the Siwalik hills it is characteristic of the dry upper slopes and ridges on sandstone and conglomerate, in somewhat stunted form, but reproducing freely, its chief companions being *Anogeissus latifolia*, *Ougeinia dalbergioides*, *Shorea robusta*, *Buchanania latifolia*, and *Pinus longifolia*.

In its natural habitat the absolute maximum shade temperature varies from 103° to 118° F., the absolute minimum from 30° to 55° F., and the normal rainfall from 30 to 150 in.

LEAF-SHEDDING, FLOWERING, AND FRUITING. In northern India the leaves turn brown and fall in March-April and the new leaves appear in May-June.

The fragrant flowers, dull purple, yellow within, in viscidly hairy panicles, appear from April to June with or before the new leaves. The fruit becomes full-sized though still unripe early in the cold season, but does not dehisce until about March to May. The fruit is a long cylindrical two-valved capsule 15-24 in. long by 0.6-0.8 in. in diameter, dark grey with raised white specks, containing a corky cylindrical dissepiment along which, in notches, the seeds are arranged. When the trees are leafless the masses of long pendent capsules give them a curious dark grey appearance. The seed (Fig. 260, *a*) is pale yellowish brown, and consists of a central bony axis 0.3-0.4 in. long with a pair of light delicate papery wings, one on either side of the axis, set somewhat obliquely like an electric fan, the whole 1-1.5 in. broad. The capsules usually dehisce on the tree, the light winged seeds escaping and being carried some distance by the wind; occasionally the capsules are blown down and dehisce on the ground. Dehiscence is gradual, and the seeds may be seen escaping a few at a time. The empty capsules often remain many months on the tree. As far as tests at Dehra Dun show, the fertility of the seed is not very high, and if kept for a year it loses its vitality almost entirely. The seeds are collected by plucking the capsules off the trees before they dehisce and placing them in the sun until they open.

GERMINATION (Fig. 260, *b-e*). Epigeous. The radicle emerges from one end of the bony central axis of the seed; the cotyledons, enclosed in the winged seed-coat, are pushed vertically upwards by the elongation of the hypocotyl, and the seed-coat falls with the expansion of the cotyledons.

THE SEEDLING (Fig. 260).

Roots: primary root long, at first thin and delicate, afterwards thick, fleshy, and yellowish brown: lateral roots numerous, fibrous, with nodules. **Hypocotyl** distinct from root, 0.6-0.9 in. long, terete, tapering slightly upwards, green or reddish turning light brown, finely pubescent. **Cotyledons**: petiole 1-1.5 in. long, finely pubescent: lamina 0.35-0.6 in. by 0.5-0.7 in., foliaceous, somewhat fleshy, broadly ovate or orbicular, usually broader than long, retuse or cleft to about one-fourth the length, base truncate or sub-cordate, entire, minutely pubescent. **Stem** erect, terete, pubescent, with leaves crowded together and internodes up to 0.4 in. long. **Leaves** opposite, exstipulate, at first several simple, followed usually by a pair of 3-foliate, followed by 5- or 7-foliate leaves; sometimes no compound leaves appear till second season. Simple leaves sub-sessile or with petiole up to 0.5 in. long, flattened above, tomentose: leaves at first small, about 0.7 by 0.3 in. or less, becoming successively larger, up to 3.5 in. by 1.7 in. in the first season, obovate, acute, base tapering, serrate, glabrous above, pubescent or glabrescent beneath, sub-coriaceous, young leaves sometimes purplish brown.

In its early stages the seedling has a strong superficial resemblance to that of the teak, but is smooth instead of scabrous and is somewhat darker in colour. Development is ordinarily slow during the first few years, but growth is greatly stimulated by weeding. Young plants are capable of struggling well against weeds, but their development is much impeded thereby. The seedlings are drought-resistant and are fairly frost-hardy; in frosty localities they are occasionally killed back, but have good power of recovery. The leaves are somewhat brittle, and in a heavy hailstorm which occurred at Dehra Dun in 1913 the leaves of seedlings were torn to pieces, suffering more than those of most other species. The seedling produces a long and somewhat

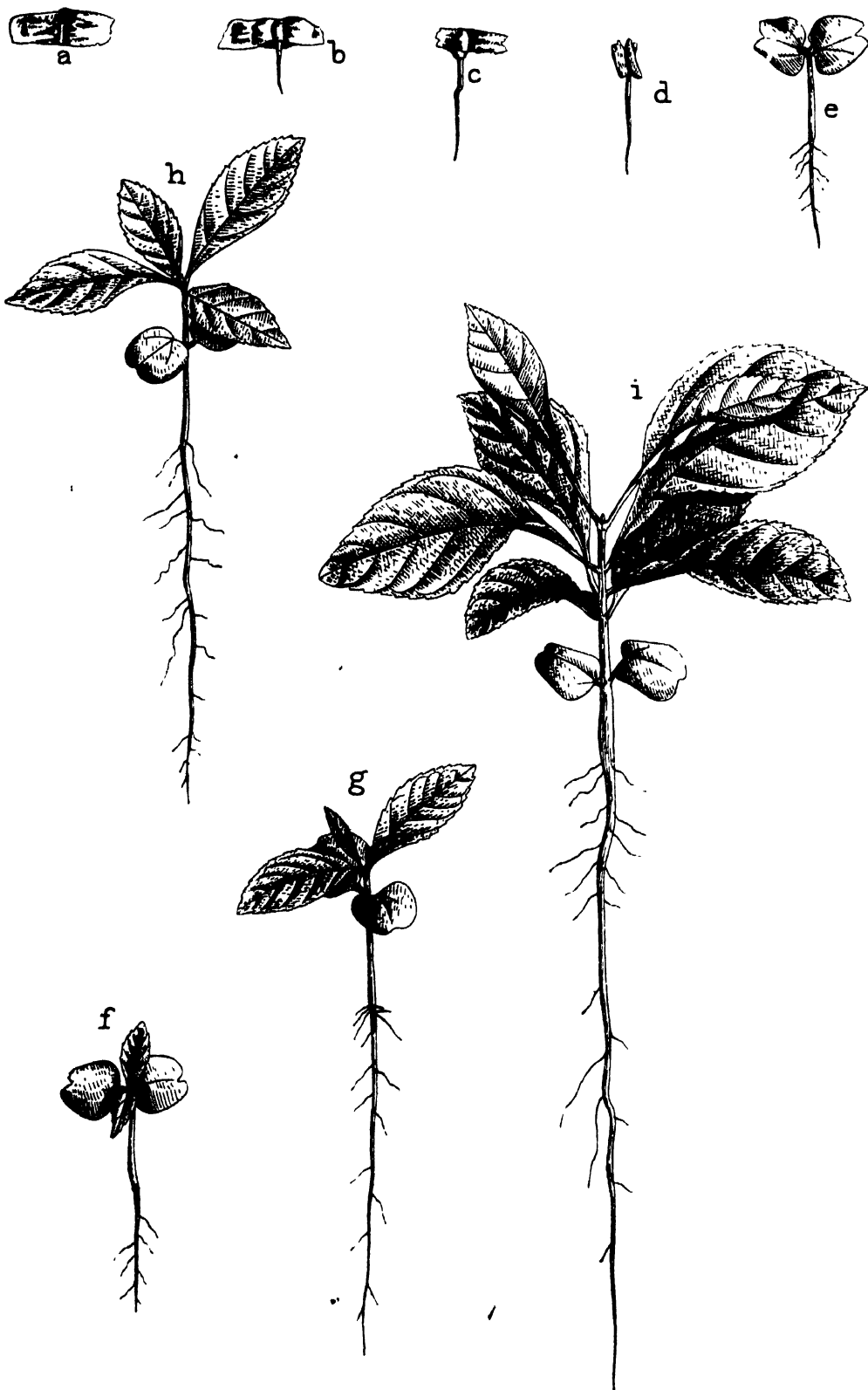


FIG. 260. *Stereospermum suaveolens*. Seedling $\times \frac{5}{8}$.
a, seed ; b-e, germination stages ; f-i, development of seedling during first season.

fragile taproot, which thickens considerably in the second year. Growth ceases about October–November, the leaves often turning reddish brown in the winter; new growth starts in April (northern India). The following measurements of seedlings grown under different conditions at Dehra Dun, in each case in full sunlight, give some indication of the rate of growth and exhibit in a striking manner the beneficial effects of weeding:

Stereospermum suaveolens: rate of growth of seedlings under different conditions, Dehra Dun.

Condition under which grown.	Height at end of season.			
	1st season.	2nd season.	3rd season.	4th season.
) In nursery, watered and weeded	Maximum 0 ft. 2½ in.	..	..	..
) In nursery, watered and weeded	Maximum 0 ft. 7 in.	..	..	..
) Broadcast sowing, irrigated, unweeded	Maximum 0 ft. 2½ in.	Maximum 0 ft. 5 in. (dense grass and weeds)	0 ft. 2½ in.–0 ft. 6 in. (dense grass and weeds)	..
) Broadcast sowing, unirrigated, unweeded	Maximum 0 ft. 3 in.	Maximum 0 ft. 5 in. (dense grass and weeds)	Maximum 0 ft. 9 in. (dense grass and weeds)	..
) Broadcast sowing, unirrigated, weeded	Maximum 0 ft. 3½ in.	Maximum 1 ft. 6 in. (vigorous)	0 ft. 7 in.–6 ft. 0 in. (larger plants vigorous, suppressing the smaller ones)	Maximum 11 ft. (maximum girth 6 in.; dominant stems vigorous, suppressing the smaller ones)

SILVICULTURAL CHARACTERS. The tree is a moderate light-demander. It resists fire well, and young plants have good power of recovery when burnt back. It is not readily browsed by cattle or goats, but is not entirely immune from damage by browsing. It is decidedly frost-hardy, and in the sub-Himalayan tract is often one of the few trees capable of surviving on grassy blanks subject to frost: in the severe frost of 1905 it escaped injury entirely in some localities, but suffered to some extent in others. In the abnormal drought of 1907 and 1908 in the forests of Oudh it proved to be conspicuously hardy. It produces suckers from lateral roots, these roots being often of considerable thickness.

NATURAL REPRODUCTION. Under natural conditions germination begins early in the rainy season and continues for some time during that season. Various circumstances favour the reproduction of this species; the seed falls for the most part after the fire season, while the seedlings are hardy, are not readily browsed, have good power of recovery from damage by fire or other injury, and persist well in a growth of grass and weeds if these are not excessively dense. Natural reproduction of seedlings and suckers is often abundant in unpromising situations such as dry exposed hill-sides. As in the case of many species with winged seeds, natural reproduction often springs up readily on land which has been ploughed up for cultivation.

ARTIFICIAL REPRODUCTION. Weeded line sowings as well as transplanting from the nursery can be carried out successfully. For nursery purposes fresh seed should be sown about April–May, preferably in light porous sandy soil, covered lightly and watered: the seedlings ordinarily begin to appear in about

two weeks and should be regularly weeded and somewhat sparingly watered. Transplanting with entire roots is difficult except during the first rainy season while the plants are still small, and even then care is necessary. Complete success has been attained at Dehra Dun by transplanting during the second rainy season after pruning the stem down to about an inch from ground-level and trimming the roots down to a length of about 9 in.

RATE OF GROWTH. The following results of girth measurements in high forest sample plots are available :

Stereospermum suaveolens : rate of growth in high forest sample plots.

Province.	Forest division.	Locality.	Number of years under measurement.	Number of trees under measurement.	Girth classes.	Mean annual girth increment for period.
					ft.	in.
United Provinces	Saharanpur	Lakarkot and Malowala	6 and 12	2	0-1	0.52
				2	1-2	0.52
				2	2-3	0.43
				1	3-4	0.63
	Lansdowne	Andhermajheri	17	10	1½-4	0.25
				14	1½-4	0.28
				3	1½-3	0.24
				2	1½-3	0.31
	Ramnagar	Rehar	19	15	1½-3	0.20
				1	2-3	0.22
Central Provinces	Balaghat	Raigarh and Baihar	8	3	3-4	0.20
				1	4-5	0.15
				23	1-2	0.17
				2	2-3	0.18

These figures indicate a comparatively slow rate of growth. A cross-section in the silvicultural museum at Dehra Dun showed 53 rings for a girth of 5 ft., giving a mean annual girth increment of 1.13 in.

Coppice measurements made in 1886 by Mr. A. F. Broun at Bullawala near Dehra Dun gave the following results for *Stereospermum suaveolens* as compared with sal :

Stereospermum suaveolens : coppice measurements, Bullawala, Dehra Dun.

Age. years.	Mean height.		Mean girth.	
	<i>Stereospermum.</i> ft.	Sal. ft.	<i>Stereospermum.</i> in.	Sal. in.
8	20	13.2	9.0	7.1
10	17	11.9	9.0	5.9

Measurements made in 1910 by Mr. C. M. McCrie in coppice coupes in the Gorakhpur district, United Provinces, gave the following results :

Stereospermum suaveolens : coppice measurements, Gorakhpur.

Age. years.	Mean height.		Age. years.	Mean height.	
	<i>Stereospermum.</i> ft.	Sal. ft.		<i>Stereospermum.</i> ft.	Sal. ft.
2	3.0	3.0	10	8.3	15.3
4	5.0	7.0	12	9.0	17.5
6	6.5	10.3	14	9.6	19.2
8	7.4	13.0	16	10.0	20.9

2. *Stereospermum chelonoides*, DC. Vern. *Padri*, *pader*, *para*, Hind. ; *Padal*, Mar. ; *Mukarti*, Kan. ; *Padri*, Tam. ; *Thakutpo*, Burm.

A large deciduous straight-stemmed tree, in unfavourable situations a small tree, with imparipinnate leaves clustered towards the ends of the branchlets. Bark grey to brown, fairly smooth. Wood hard, grey, used for building, furniture, tea-boxes, canoes, &c.

DISTRIBUTION AND HABITAT. Sub-Himalayan tract from Oudh (Gonda forests, not common) eastward to Assam, common up to 2,000 ft. in the eastern Himalaya, Chittagong, throughout Burma in mixed deciduous forests, ascending to 4,000 ft. in the Shan hills; the Indian Peninsula, chiefly on the western side, rare in Chota Nagpur and Orissa, fairly common in valleys in the Central Provinces, in Bombay chiefly in the moist forests of the Konkan and North Kanara; common in the deciduous forests of Travancore up to 4,000 ft. (Bourdillon).

This tree does not extend to such dry regions as *S. suaveolens*. In its natural habitat the absolute maximum shade temperature varies from under 100° to 115° F., the absolute minimum from 35° to over 60° F., and the normal rainfall from 40 to 150 in.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The leaves are shed about February–March, the new leaves appearing in April. The fragrant flowers, yellow marked with red, in lax drooping panicles, appear before, with, or after the new leaves from April to June. The fruits ripen in the following cold season; the time of their dehiscence has not been accurately recorded. The capsules are slender, 10–30 in. long by 0.25–0.5 in. in diameter, with a thick septum in the deep notches of which the seeds lie; the seeds are wedge-shaped and winged, about 1.25 in. broad with the wings.

SILVICULTURAL CHARACTERS. The silvicultural characters of this tree require study. It produces root-suckers freely and coppices well. It is probably less hardy than *S. suaveolens*.

RATE OF GROWTH. Gamble's specimens averaged 7 rings per inch of radius, giving a mean annual girth increment of 0.9 in.

3. *Stereospermum xylocarpum*, Benth. and Hook. f. Syn. *Bignonia xylocarpa*, Roxb.; *Spathodea xylocarpa*, T. And. Vern. *Paral*, C. P.; *Kharsing*, Mar.; *Genasing*, Kan.

A moderate-sized to large deciduous tree with very large bi- or tripinnate leaves up to 4 ft. long. Bark light grey, fairly smooth, flaky. Wood hard, tough, and elastic, with a small orange-brown heartwood, used for cart-shafts and cabinet work.

This is a tree of the Indian Peninsula in deciduous forests of the Central Provinces, Bombay from Khandesh southwards, and Madras southwards to Travancore. It is leafless for a short time in the hot season. The large fragrant white or pinkish flowers appear in April–May and the capsules ripen next hot season. The latter are conspicuous from their large size, being sometimes as much as 3 ft. in length, woody and tubercled, with a central septum about 0.5 in. thick. The winged seeds are about 1.25 in. broad.

The silviculture of this tree requires study. It is a light-demander, though it stands some shade in youth: it produces root-suckers. Bourdillon gives the rate of growth as about 9 rings per inch of radius, or a mean annual girth increment of 0.7 in.

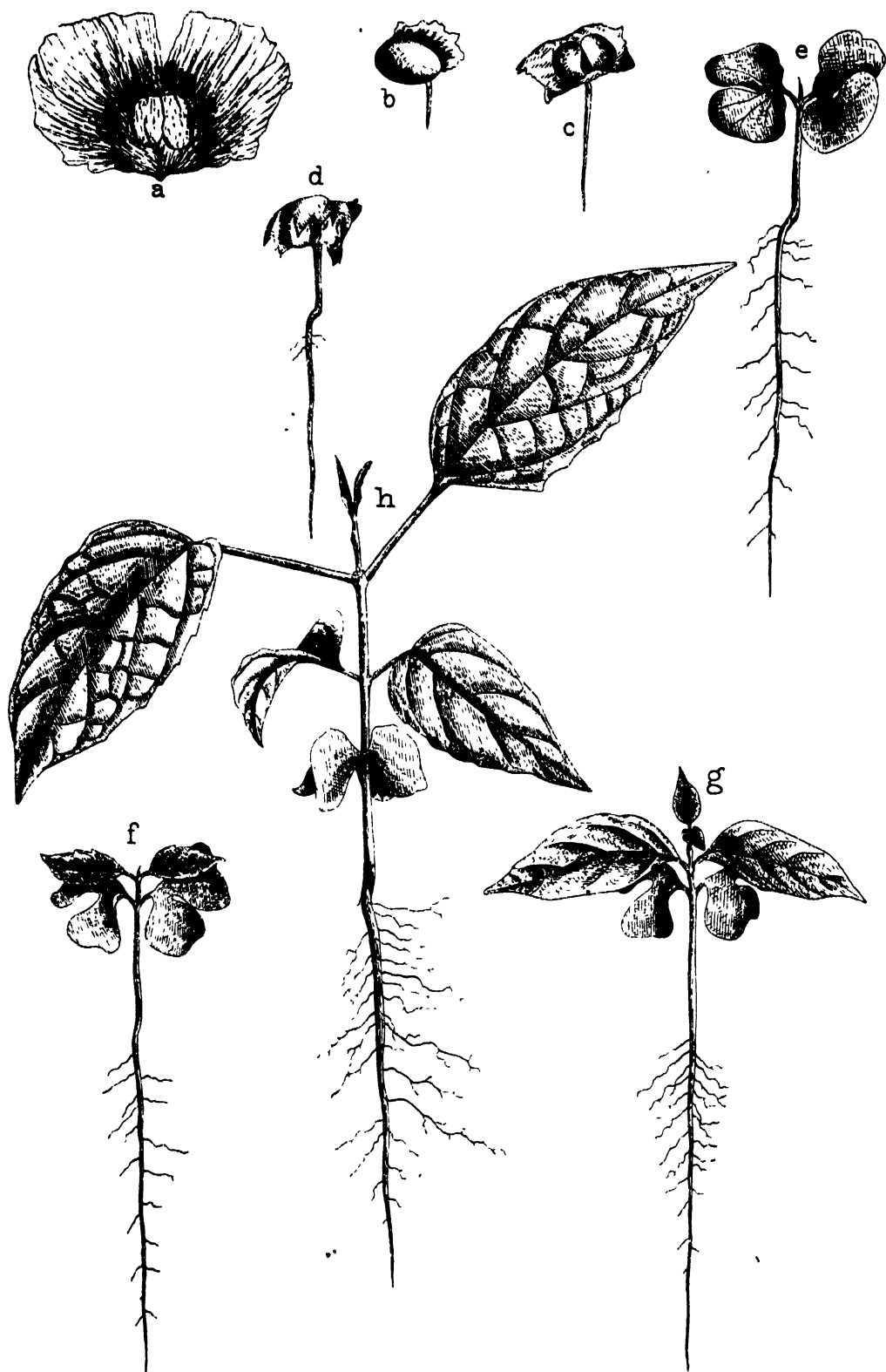


FIG. 261. *Oroxyllum indicum*. Seedling $\times \frac{5}{8}$.
 a, winged seed ; b-e, germination stages (wing of seed almost wholly removed) ; f-h, development of seedling during first season.

4. *Stereospermum neuranthum*, Kurz. Vern. *Thandè*, Burm.

A deciduous tree of the mixed deciduous forests of Burma. It is fairly common both in the upper and in the lower mixed types. It produces root-suckers. The wood is hard and of very fair quality.

2. *OROXYLUM*, Vent.

Oroxylum indicum, Vent. Syn. *Calosanthès indica*, Bl. Vern. *Pharrái*, *ullu*, *sauna*, Hind.; *Tetu*, Mar.; *Pana*, Tam.; *Kyaungya*, Burm.

A small deciduous tree with few branches and very large opposite compound leaves 3-5 ft. long, tripinnate near the base, bipinnate in the centre, and once pinnate towards the apex: when leafless the branches are easily recognized from the large opposite leaf-scars. Bark light greyish brown, soft. Wood yellowish white, soft, not used; bark used for tanning and dyeing. The tree is a conspicuous one in the forests of India, especially when leafless and bearing its large scabbard-like capsules.

DISTRIBUTION AND HABITAT. Throughout the greater part of India and Burma except in the driest regions, chiefly in deciduous forests, but sometimes scattered in evergreen forest, and often in ravines and other moist places; also in the Andamans and Ceylon. In the sub-Himalayan tract it ascends to 3,500 ft.; it is rare west of the Jumna.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The leaves usually turn a dark coppery brown in the cold season, falling from December to February; the new leaves do not appear till May-June. The large fleshy purplish but not handsome flowers, in stout terminal racemes, appear from May to August; the fruits develop rapidly, attaining full size by the beginning of the cold season and dehiscing usually from February to May. The fruit is a large conspicuous two-valved flat woody capsule 1-3 ft. long and 2-3.5 in. wide, containing a large number of seeds. The seeds (Fig. 261, *a*) are flat and are surrounded by a thin transparent white papery wing, the whole 2-2.7 in. across; the testa is thin, delicate, and membranous, enclosing a light green flat embryo 0.5 in. in diameter faintly visible from the outside. About 280-340 seeds weigh 1 oz.; they are carried by wind to some distance from the tree. If carefully stored the seed retains its vitality for at least a year, a sample kept for a year and tested at Dehra Dun showing 95 per cent. of success. If exposed to moisture or other adverse conditions, however, the seed becomes rapidly spoiled.

GERMINATION (Fig. 261, *b-e*). Epigeous. The soft delicate testa, resembling a thin layer of pith and capable of absorbing and retaining moisture during germination, together with the membranous wing, usually rots off in part or becomes partly washed off by rain during germination. The radicle emerges first, the hypocotyl then elongating and carrying above ground the large leafy bifid cotyledons, which soon expand, the remains of the testa being either left in or on the ground or carried up, dropping with the expansion of the cotyledons.

THE SEEDLING (Fig. 261).

Roots: primary root long, thick, terete, tapering, whitish: lateral roots fairly numerous, fibrous, distributed down main root. **Hypocotyl** distinct from root, 0.9-1.1 in. long, somewhat compressed, tapering slightly upwards,

green, minutely pubescent. *Cotyledons*: petiole 0.2–0.25 in. long, channelled above, minutely pubescent; lamina 0.6–0.8 in. by 1.2–1.5 in., foliaceous, much broader than long, deeply bifid, lobes reniform and sometimes partly overlapping each other, entire, minutely pubescent above, glabrous beneath; each lobe with three principal veins from the base, subsidiary veins reticulate. *Stem* erect, slightly compressed; glabrous or young parts minutely pubescent; internodes up to 1 in. long in younger stages. *Leaves* opposite, exstipulate, first few pairs simple, followed by one or more pairs of 3-foliate leaves, and then by 5-foliate leaves, which are usually produced in the second season. Simple leaves with petiole 0.5–2 in. long, glabrous, channelled above; lamina 2–4 in. by 1.3–2 in., ovate acuminate, entire or dentate, base often decurrent, glabrous, or veins on lower surface minutely pubescent; venation arcuate reticulate, veins depressed on upper surface and prominent beneath.

The growth of the seedling is slow to moderate, maximum heights of about 6 in., 1 ft., and 2½ ft. being attained by the end of the first three seasons if no weeding or watering is done, and nearly double these dimensions being attained if the plants are weeded and watered. Young seedlings are sensitive to frost and to drought, many dying off in the hot season in dry situations exposed to the sun; they benefit by moderate shade and moisture. The leaves of seedlings turn reddish brown in the cold season, falling in December–January, after which the seedlings are leafless until March, when new growth commences (northern India).

SILVICULTURAL CHARACTERS. The tree stands moderate but not heavy shade. Its root-system is superficial, and it produces root-suckers in great profusion, these often forming a dense growth round the parent stem.

NATURAL REPRODUCTION. Under natural conditions the seed germinates early in the rainy season. For successful reproduction a certain amount of shade and moisture appears to be necessary in the early stages, owing to the tendency of the seedlings to die of drought in hot exposed situations. Otherwise seedlings have good power of making their way through a moderate growth of grass and weeds.

ARTIFICIAL REPRODUCTION. Nursery-raised seedlings can be transplanted without difficulty during the first and second rainy seasons. The seed should be sown in the nursery in March or April, and lightly covered with earth, the beds being regularly watered, slightly shaded, and protected from frost in winter. The tree may also be propagated by transplanting root-suckers.

RATE OF GROWTH. Gamble's specimens gave 2½ to 4 rings per inch of radius, or a mean annual girth increment of 1.57 to 2.52 in., which is fast.

3. MILLINGTONIA, Linn. f.

Millingtonia hortensis, Linn. f. Syn. *Bignonia suberosa*, Roxb. Indian cork-tree. Vern. *Akás nim*, Hind.; *Kat malli*, Tam.; *Kavuki*, Tel.; *Egayit*, Burm.

A tall, handsome tree, with an elongated crown and large bipinnate, sometimes tripinnate leaves. Bark dark yellowish grey, corky. Wood soft, yellowish white, of very fair quality, suitable for tea-boxes and similar purposes. The tree is believed to be indigenous in Burma, and is largely cultivated for ornament throughout India. It is fast-growing, tall, and straight, and, as Gamble rightly suggests, it is well worth considering as a useful soft-wood for

plantation purposes, though it does not appear to have been tried as such. In October–November (northern India) it is covered with drooping masses of very fragrant white to pale pink flowers with long slender corolla-tubes, which perfume the air around. The fruit, a flat linear capsule, about 1 ft. long with numerous delicately winged seeds, ripens towards the end of the hot season ; seeds are rarely produced in northern India.

The tree is decidedly hardy, and is not particular as to soil ; although it grows best in a moist climate it does fairly well in dry situations, growing well in Lahore Cantonment without irrigation, which not many trees are capable of doing. It is, however, brittle and shallow-rooted, and is liable to be broken or uprooted by strong winds. It has a tendency to send up root-suckers in great profusion, which is a disadvantage in gardens. It is easily raised from seed when obtainable, from cuttings put down in the spring, or from root-suckers dug up and transplanted during the rainy season. Seed should be sown in the nursery as soon as it ripens, towards the end of the hot season, and the seedlings, which bear transplanting well, should be planted out a year later at the beginning of the rainy season.

The growth is fast. Gamble's specimens gave four to five rings per inch of radius, representing a mean annual girth increment of 1.26 to 1.57 in.

4. TECOMA, Juss.

Tecoma undulata, G. Don. Syn. *Tecomella undulata*, Seem. Vern. *Lahura*, Punj. ; *Lohero*, Sind ; *Raktarohida*, Mar. ; *Rori*, Bal.

A shrub or small tree, nearly evergreen, with simple grey leaves and large yellow to orange flowers, which appear from January to April, when the tree is a very handsome sight. The fruit, a curved capsule 6–8 in. long, ripens from May to July. The wood is yellowish brown, mottled, handsome, highly prized for furniture, carving, and agricultural implements (Brandis).

This is a tree of the driest regions of India, namely the Suliman and Salt Ranges, Sind, Baluchistan, trans-Indus, Punjab, ascending to 4,000 ft. in the outer Himalaya, Rajputana, Guzerat, and Khandesh. It is sometimes planted in gardens. It coppices fairly well, and is easily grown from seed or cuttings. It is readily browsed by cattle. It is drought-hardy and very resistant to fire. It would be a useful species for afforesting dry tracts.

ORDER XLV. ACANTHACEAE

This order, consisting chiefly of herbaceous plants, contains some undergrowth shrubs and climbers of indirect importance in Indian forestry.

Genera 1. ACANTHUS, Linn. ; 2. ADHATODA, Nees ; 3. PHLOGACANTHUS, Nees ; 4. STROBILANTHES, Bl.

1. ACANTHUS, Linn.

Acanthus ilicifolius, Linn.

A spinescent shrub of the mangrove forests where it sometimes forms a dense undergrowth troublesome in wood-cutting operations.

2. ADHATODA, Nees.

Adhatoda Vasica, Nees. Syn. *Justicia Adhatoda*, Linn.

A gregarious shrub, abundant in the sub-Himalayan tract, and ascending the outer hills to 4,000 ft. It appears in great quantity on waste places, where it persists and spreads owing to its immunity from damage by browsing. It also forms a dense undergrowth in riverain forests of *Acacia Catechu* and *Dalbergia Sissoo*, and sometimes also in mixed deciduous forests.

3. PHLOGACANTHUS, Nees.

Phlogacanthus thyrsiflorus, Nees.

An evergreen shrub with a large thyrsoid inflorescence of handsome brick-red flowers, frequent as an undergrowth species in moist, shady places in parts of the sub-Himalayan tract and in Burma.

4. STROBILANTHES, Blume.

This genus contains about 160 species of handsome flowering shrubs, many of which are of great importance in Indian forestry as undergrowth species. The majority are shade-bearing, and many are gregarious, forming dense masses over considerable areas and having an important bearing on the natural reproduction of trees. Although several species flower and fruit annually, many, like bamboos, flower and fruit at intervals of several years, the interval between successive flowerings being as a rule constant for each species, but varying with different species. After the flowering and fruiting the whole plant dies, and the following year the ground is covered with young seedlings commencing the next generation; this periodic dying is of importance, as will be seen below, in connexion with silvicultural operations for the eradication of the plant. When gregarious flowering takes place, bees are attracted in large numbers, while R. M., writing in the *Indian Forester*, vol. xx (1894), p. 130, remarks on the large number of jungle-fowl which were attracted by the seed during a gregarious seeding in the Nilgiris. An interesting general account of the more important Indian species is given in Gamble's *Manual of Indian Timbers* (1902), pp. 518 et seq., which may be referred to. See also *Indian Forester*, vol. xiv (1888), p. 153. The members of this genus are characteristic mainly of hilly country, the most notable exception being *S. auriculatus*, Nees, a common plant in the sal forests of the sub-Himalayan tract and the Indian Peninsula.

In no part of India is this genus so well represented as in the Nilgiris and other hills of southern India, where the plants reach a larger size than elsewhere and are found in profusion, with great variety and beauty of flowering, in the *shola* forests. *S. foliosus*, T. And., is one of the largest species, the stems attaining 4–6 in. diameter. Perhaps the commonest and best known species of the Nilgiris is *S. Kunthianus*, T. And., which prefers dry slopes on the eastern sides of the hills where there is little or no tree forest; this species flowers at intervals of four to six years, giving a bright blue colour to the landscape. The genus is also well represented in the Himalaya and the hilly parts of Assam, Burma, and the Indian Peninsula.

In the eastern Himalaya, among the commonest species are *S. pectinatus*,

T. And., and *S. divaricatus*, T. And. The former is a large shrub, attaining a height of 10 ft. and a girth of 9 in. or sometimes more ; its flowering period is twelve years (recorded 1890, 1902). In the western Himalaya, *S. alatus*, Nees, and *S. Dalhousianus*, Clarke, are common non-gregarious species of little silvicultural importance, which flower every year. The important species of this region is *S. Wallichii*, Nees (with *S. atropurpureus*, Nees, which is possibly not a distinct species). This plant, known in Jaunsar as *jhanu*, grows gregariously, forming a dense carpet in the oak and fir woods at 7,000–10,000 ft., and preventing by its thick mass of roots and stems the establishment of natural reproduction of tree species ; the results of experiments in eradicating it are described below. This plant flowers and dies at intervals of twelve years (recorded 1882, 1894, 1906, 1918). Its mode of growth is peculiar, though possibly that of other species may be similar. Each year a new shoot consisting of several internodes is sent up in the spring, but at the end of the season the whole of the year's shoot drops off except the lowest internode of the year, so that the age of a plant can at any time be told by counting the number of old internodes.

In the Western Ghats from Bombay southwards there are several important species. Talbot enumerates thirteen species in the Bombay Presidency, of which one, *S. callosus*, Nees, is common on laterite or hard rocky ground, and extends to comparatively dry trap regions of the Satpuras in Khandesh and Central India. This species, known in Bombay as *karvi*, flowers at intervals of seven or eight years ; its stems are used with mud plaster for walls of huts, and when it flowers and dies the dry stems are largely collected for fuel. Of other gregarious species of the Western Ghats, which are said to flower at intervals of about seven years, may be mentioned *S. reticulatus*, Stapf (vern. *akra*), *S. barbatus*, Nees, *S. sessilis*, Nees (flowers every seven or fifteen years ?), and *S. perfoliatus*, T. And.

In Burma there are species which form a dense undergrowth in teak forests, hindering reproduction. Mr. C. W. A. Bruce¹ describes the gregarious flowering of *S. rufescens* in the teak forests of the Upper Chindwin district. This plant is said to flower once in six years, when it clothes the forest undergrowth with masses of strongly-smelling blue flowers which attract innumerable bees ; the flowering was observed in March, the plants seeded early in April, and the dead stems acted as a protection against fire, no doubt because they had killed out the grass and weeds and were themselves less inflammable than these.

The silvicultural importance of the gregarious members of this genus lies in their effect on the natural reproduction of tree species, and it will be useful to consider the results of efforts made to eradicate them. It does not always follow, however, that it is necessary or even advisable to eradicate the plant, for, in the case of the larger species at all events, it may afford a useful shelter to shade-bearing tree species in early youth, and its eradication may result in the entry of weeds of a more noxious description. The eradication of *S. Wallichii*, Nees, has been carried out experimentally from time to time at Deoban, near Chakrata, in the western Himalaya, where it exists as a dense carpet under *Quercus semecarpifolia*, and prevents seedlings of that species

¹ Ind. Forester, xxi (1895), p. 47.

and of firs from establishing themselves. Mere uprooting of the shrub has given satisfactory results, but the cost amounted to over Rs. 6 per acre. Also since there are often tree seedlings among the *Strobilanthes* these stand in danger of being uprooted during the process. Advantage was therefore taken of the gregarious flowering of 1906 to ascertain if the cutting of the flowering or fruiting stems would have any effect. The flowers began to appear in the first week of July, the seed ripened from the middle of September to the middle of October, and the plants died by the first week in November. The cutting of the flowering shoots was commenced in the middle of July, but this was found to be ineffectual, as new flowering shoots were produced, and cutting had to be repeated two or three times. It was found eventually that the best time to cut the stems was immediately before the seed ripened, that is, in September. An experimental plot was kept under observation for six years subsequently, and during this time no *Strobilanthes* seedlings appeared, while numerous oak seedlings succeeded in establishing themselves. Many oak seedlings were found to date from the time when the *Strobilanthes* was eradicated, but many on the other hand were older, which indicates that the oak seedlings were able to persist in spite of the dense covering of *Strobilanthes*, though they were assisted greatly by its removal.

Outside this plot the *Strobilanthes* was observed to commence germination in the first week of September of the year following the seeding, and within a year or two the ground was again carpeted with seedlings. The plant is a favourite fodder of sheep, goats, and buffaloes, and it was suggested that the admission of grazing before the fruit ripened would have the same effect as cutting; the owners of the animals, however, refused to allow them to graze, on the ground that the unripe fruits are injurious, although after the seed ripened they ate the fruits readily without harm. There can be little doubt that even without artificial measures for eradicating *Strobilanthes*, natural reproduction of tree species benefits greatly each time the plant dies naturally, for it takes two or three years at least for the new generation to reach a size large enough to be troublesome.

Mr. B. B. Osmaston¹ mentions that in the case of *S. pectinatus*, T. And., a large shrubby species in the Darjeeling hills, an experiment made during the gregarious flowering of 1902 showed that it could be eradicated successfully if cut in the month of June, when it had commenced to flower; in this it differs from *S. Wallichii*.

Mr. J. S. Gamble² has described the measures taken in the eradication of *Strobilanthes* in the Nilgiris, and the following passage may be quoted:

'So dense is the thicket of *Strobilanthes* in the undergrowth of the forests, that under ordinary natural circumstances it is really only at the time of the periodical flowerings that the tree seedlings get a chance of a start. There are usually thousands to be found under the thicket, but until the *Strobilanthes* dies, or is cut away, they simply remain stunted, waiting until the removal of the cover gives them a chance, and then they usually take advantage of it and come on quickly. It has, consequently, on the Nilgiris been lately found useful to assist in disengaging the seedlings by clearing away the growth of *Strobilanthes*. In the forests round Ootacamund and Coonoor, where there is a large demand by the poorer classes of natives for small fuel, and where the

¹ Ind. Forester, xxx (1904), p. 195.

² Ibid., xiv (1888), p. 154.

hard, brightly burning wood of the *Strobilanthes* is much appreciated, it is possible to clear away the growth of it and not only allow of the young tree seedlings getting a chance of growing, but provide a considerable amount of fuel ample, at very cheap rates, to cover the whole cost of the work. In the Lamb's Rock forest, 37 acres cleaned in 1886, at a cost of Rs. 222, produced 9,038 head-loads of fuel (about 323 tons), realizing at one anna each, Rs. 565, equivalent to a net profit of Rs. 9-4-0 per acre. Something like nine-tenths of the material cut consisted of *Strobilanthes*. The good results of this work were most marked: myriads of seedlings were disengaged, and a few years hence, with the help of a seed cutting or cutting under selection in the cover, what was a few years ago merely a dilapidated *shola* with cover of old, mostly unsound, trees and underwood of *Strobilanthes*, will be converted into a fully stocked pole forest. It may easily be understood that the clearing of *Strobilanthes* must precede the seed cutting or the cutting under selection (*jardinage*). When the cover overhead in a forest is light, the bank of *Strobilanthes* underneath is often very valuable as assisting to retain the moisture in the soil, prevent fires, and nurse the tree seedlings, and in some cases it is best not to clear away the growth too wholesale, but to disengage seedlings in plots where they are found sufficiently thick and good. An example of a *shola* in which not only the *Strobilanthes* were cut, but also the covering trees some years ago, may be seen in the valley at the back of the inspection house at Naduvattam. There, the growth of new *Strobilanthes* and tree seedlings together is so thick as to be at the disadvantage of the latter; and, did funds admit, the *Strobilanthes* should now be thinned out.'

ORDER XLVI. VERBENACEAE

The chief importance of this order lies in the fact that it contains the principal timber tree of India, and one of the most important in the world, namely the teak, *Tectona grandis*, Linn. f. It contains also other trees of some importance or interest (*Gmelina*, *Vitex*, *Premna*), as well as numerous shrubs and several climbers.

Genera 1. TECTONA, Linn. f.; 2. GMELINA, Linn.; 3. VITEX, Linn.; 4. PREMNA, Linn.; 5. CALLICARPA, Linn.; 6. AVICENNIA, Linn.; 7. LANTANA, Linn.

1. TECTONA, Linn. f.

Species 1. *T. grandis*, Linn. f.; 2. *T. Hamiltoniana*, Wall.

1. *Tectona grandis*, Linn. f. Teak. Vern. *Ságun*, Hind.; *Ságwan*, *ság*, Mar.; *Tegu*, *tegina*, Kan.; *Teku*, Tel.; *Thekku*, Tam., Mal.; *Kyun*, Burm. (Fig. 262.)

A large deciduous tree with a rounded crown and, under favourable conditions, a tall clean cylindrical bole, which is often buttressed at the base and sometimes fluted. Branchlets quadrangular, channelled, with a large quadrangular pith. Leaves opposite, large, broadly elliptical or obovate, usually 1-2 ft. long, but often larger in coppice-shoots and young plants, rough above, stellately grey tomentose beneath, with minute glandular dots, which are red in young leaves, afterwards turning black. Bark, 0.15-0.7 in. thick, grey or light greyish brown, fibrous, with shallow longitudinal fissures, exfoliating in long, thin, narrow somewhat corky flakes.

Measurements of bark thickness in various localities in Bombay and the Central Provinces showed averages of 0.15 to 0.4 in. for trees of small to

moderate size, and gave a general average of about 0.25 in. Measurements in the Nilambur plantations gave the following average bark thicknesses :

Girth of tree, 1-2 ft. ;	bark thickness, 0.5 in.
„ „ „ 2-3 ft. ; „ „	0.55 in.
„ „ „ 3-4 ft. ; „ „	0.65 in.
„ „ „ 4-6 ft. ; „ „	0.7 in.

Wood moderately hard. Sapwood small, whitish. Heartwood dark golden yellow, sometimes with dark streaks, turning brown with age, oily, with a characteristic odour, extremely durable, seasons well, and does not warp or split.

The teak is the most important timber tree of India. For ship-building, its timber stands in a class by itself, and has a world-wide reputation. It is also extensively used for house-building, bridge and wharf construction, piles, furniture and cabinet-work, railway carriages and wagons, carving, ordnance work, wheel spokes and felloes, general carpentry, and numerous other purposes. Teak timber is largely exported from Burma to Europe.

Under favourable conditions the teak reaches large dimensions. Bourdillon¹ records a tree in the Achencoil valley, Travancore, 26 ft. in circumference, but it had a short bole ; he mentions that at the beginning of last century, when the British Naval Department were collecting teak in Travancore, a tree was felled in the Idiyera valley which measured 7 ft. in diameter at its butt and 26 in. at a length of 70 ft., and therefore contained 900 cubic ft. of timber. In the Anamalais Beddome records trees above 22 ft. in girth, with boles 80 or 90 ft. to the first branch. Mr. K. R. Venkatramana Iyer² records an exceptionally tall tree standing in evergreen forest near the Karumpoya river in the Edakutti forest, South Malabar ; it had a height of 192 ft., a clean straight trunk to the first branch of 114 ft., and a girth at base of 16 ft. 8 in., and at 4½ ft. from ground-level of 15 ft. 10 in. Mr. H. Tireman³ records a tree felled in the forests of southern Coorg which had a girth at breast-height of 25 ft. 2 in., and yielded three logs with the following measurements :

- (1) Length 11 ft. 7 in. ; mean girth 18 ft. 6 in. ; out-turn 248 cubic ft.
- (2) „ 11 ft. 4 in. ; „ „ 16 ft. 1 in. ; „ 182 „ „
- (3) „ 10 ft. 3 in. ; „ „ 14 ft. 4 in. ; „ 132 „ „

Total 562 „ „

Muhammed Habibullah Sahib⁴ records a tree felled in the Tekkadi leased forests, South Coimbatore. The girth at breast-height was 18 ft. 7 in., and the tree yielded eleven logs totalling 711 cub. ft. Mr. A. Wimbush⁵ records a tree recently felled at Palacadava in South Coimbatore which yielded five logs totalling 1,099 cub. ft.

Among large trees recorded from Burma may be mentioned one measured by Dr. Brandis in the Gwethe forest, Toungoo, with a girth of 16 ft. at 6 ft. from ground-level, and a clear bole to the first branch of 114 ft. A tree 19 ft. in girth at 6 ft. from ground-level is recorded in the working plan of the Kadin-bilin forest, Tharrawaddy, 1885. In the Myittha-Panlaung forest, Mr. H.

¹ Forest Trees of Travancore, p. 285.

² Ind. Forester, xxxix (1913), p. 174.

³ *Ibid.*, xlv (1918), p. 86.

⁴ *Ibid.*, p. 468.

⁵ *Ibid.*, xlv (1920), p. 247.



FIG 262 *Tectona grandis*, girth 11 ft 7 in Mnyo, Toungoo, Burma

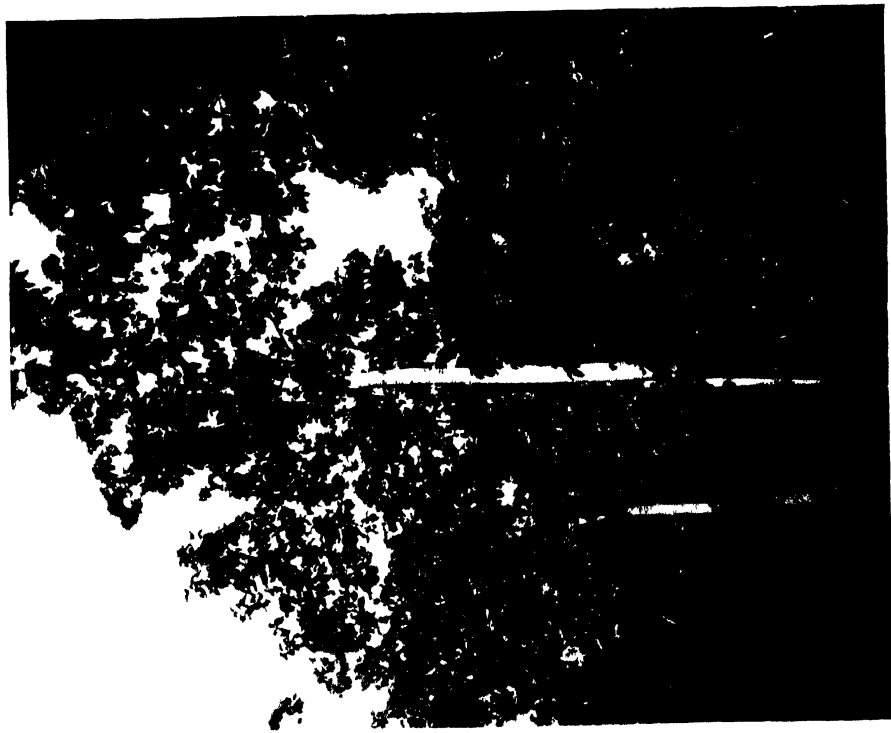


FIG 263 Teak tree height 152 ft girth 10 ft 3 in bole 93 ft estimated to contain 282 cubic ft of timber Mohanm reserve Katha Upper Burma Note main at base



FIG 264 Pure teak forest Mohanm Katha Upper Burma Tree in centre with main at base 11 ft 4 in in girth 135 ft in height 93 ft bole estimated to contain 120 cubic ft of timber

Calthrop measured a tree 20 ft. in girth at 6 ft. from the ground, with a clear bole of 60 ft. to the first branch. Two trees measured by me in 1906 in the Mohnyin forest, Katha, had the following dimensions :

- (1) Girth at breast-height 10 ft. 3 in., height 152 ft., bole 93 ft., estimated to contain 282 cub. ft. of timber.
- (2) Girth at breast-height 11 ft. 4 in., height 135 ft., bole 93 ft., estimated to contain 320 cub. ft. of timber.

These two trees are shown in Figs. 263 and 264.

Mr. C. G. Rogers¹ records the cubic contents of five trees recently felled and logged in the Mehaw reserve, Pyinmana, as follows :

	No. of logs yielded.	Total length of logs.	Mean girth of bottom log.		Total volume.
		ft.	ft.	in.	cub. ft.
(1)	6	153	13	6	862
(2)	3	78	13	6	663
(3)	3	81	13	6	737
(4)	3	86	11	3	531
(5)	4	72	18	0	687

These trees grew on rich well-drained soil at the foot of the hills east of the Sittang river. Mr. Rogers also records in the Gamôn reserve of the Zigôn forest division, a tree with a height of 153 ft. and a breast-height girth of 15 ft. 10 in.

Among large logs recorded from Burma is one mentioned by Dr. J. Nisbet.² It was cut in the Shweli forests, Ruby Mines district, by Messrs. Darwood & Co., and launched in one of the floating streams about 1898 ; it was quite sound, had a length of 82½ ft., a butt girth between 12 and 13 ft., a top girth between 7 and 8 ft., and a mean girth of 10 ft., and contained 516 cub. ft. of timber. Another sound log recorded by Mr. S. Carr³ in the Yamethin district had a length of 64 ft. and a mean girth of 13 ft. 9 in., giving a volume of 756 cub. ft.

GENERAL DISTRIBUTION. Teak is indigenous throughout the greater part of Burma and the Indian Peninsula, in Siam, and in Java and other islands of the Indian Archipelago. In Burma the northern limit of teak lies about 25° 30' N. lat., that is, some distance outside the tropics, while its southern limit is in the Amherst district between 15° and 16° N. lat. ; on the east it extends beyond the frontiers of the province, while on the west it does not extend beyond the western watershed of the Irrawaddy and Chindwin rivers. In the Indian Peninsula the northern limit of teak is in the western Aravallis in Rajputana at 24° 42' N. lat., thence eastward through Central India to the Jhansi district at 25° 33', entering the Banda district, thence in a southeasterly direction to the Mahanadi river. From this northern limit it extends southward to Tinnevely and Travancore. In Burma and the Indian Peninsula it is by no means continuous within the limits mentioned, but is confined to tracts of greater or less extent separated by other tracts where it is absent or of very local occurrence.

Although the teak reaches large dimensions in some of the forests of western and southern India, Burma is the great source of supply of large-

¹ Ind. Forester, xliv (1918), p. 417.

² Ibid., xxiv (1898), p. 320.

³ Ibid., xxii (1896), p. 465.

sized timber for the European market, and the vast teak forests of that province constitute one of its greatest natural assets. Nevertheless even the poorer classes of teak forest in the Indian Peninsula are of considerable value as sources of local supply in the shape of poles and timber for building and other purposes.

Teak has been planted in many localities outside its natural region. Plantations on a small scale have been formed in the United Provinces, Bengal (including Chittagong), Assam, Bihar and Orissa, Arakan, and the Andamans ; a short account of some of these plantations is given below (pp. 733-4). The tree is frequently planted in parks and gardens as far north as Saharanpur, Dehra Dun, and even Lahore, as well as in other places outside its natural region.

CLIMATE. Although teak occurs in dry localities, subject to great heat and drought in the hot season, it thrives best and reaches its largest dimensions in a fairly moist, warm, tropical climate, though in very moist tropical regions it tends to be replaced by evergreen forest. It extends into regions of slight frost, but throughout almost the whole of its distribution frost is unknown. It occurs where the normal rainfall is 30 in. or even less, as in Khandesh, Ahmednagar, Nimar, Buldana, and West Kurnool, and is also found where the rainfall is as much as 150-200 in., as on the west coast of India and in Tenasserim. Actually it appears to thrive best with a normal rainfall varying from 50 to 150 in. The most important teak areas of Burma are situated in regions where the normal rainfall varies from 50 to 120 in. In the Indian Peninsula it experiences in places absolute maximum shade temperatures up to about 118° F., and absolute minimum shade temperatures down to about 36° F., but these extremes denote a drier climate than is favourable to its development. In the moist parts of the west coast, where it reaches larger dimensions than in the drier parts of its Indian peninsular region, the climate is much more equable, the absolute maximum shade temperature varying from 95° to 100° F., and the absolute minimum from 55° to 62° F. In the more important teak areas of Burma the absolute maximum shade temperature varies from 102° to 110° F., and the absolute minimum from 39° to 55° F.

TOPOGRAPHY, GEOLOGY, AND SOIL. The majority of the teak forests are situated on hilly or undulating country, but there are considerable areas on flat alluvial ground provided it is well drained, not only on plains of some extent, but also on alluvial flats of limited size along the banks of rivers and streams. On well-drained deep alluvial soil teak sometimes occurs remarkably pure, and attains large dimensions. It also attains very good development on the fertile lower slopes of hills where the soil is deep, but along dry ridges it becomes stunted, as is also the case on shallow soil. Above all, the teak requires good subsoil drainage, and will not endure stiff soil which is liable to inundation or to water-logging. In the plains forests of Burma teak is sometimes confined to the fringes of well-drained ground along the banks of watercourses, avoiding the ground away from the streams where the drainage is not so good. In the Nilambur teak plantations of South Malabar, in which the stock has been carefully classified according to quality, it is found that drainage exercises a great influence on the quality. Here flat alluvial ground does not produce first quality crops unless it is close to the main river, the growth deteriorating

to second quality at a short distance from it, even where the ground is well drained by feeders ; where the drainage is at all deficient third quality is the result.

Teak is found on various geological formations, but the extent to which it flourishes depends largely on the depth, drainage, moisture, and fertility of the resulting soil. It grows well in Burma on the soft tertiary sandstones and shales of the Pegu Yoma and parts of the Chindwin drainage, where the resulting soil varies from sandy to clayey loam, usually of good depth and drainage. It is fairly plentiful in the sandstone areas of the Indian Peninsula, particularly on the Vindhyan sandstones, but on hard metamorphosed sandstone or quartzite, which disintegrates with difficulty, the teak becomes stunted and of poor growth. Teak flourishes on granite, gneiss, schists, and other metamorphic rocks in the hills east of the Sittang river, in the Ruby Mines district, and parts of the Madaya drainage of Burma, as well as in North Kanara, Malabar, the Anamalai hills, Coorg, and elsewhere in the Indian Peninsula. The soil resulting from granite and gneiss is often very sandy or gravelly and porous, and on ridges and in dry situations generally it may become unfavourable for the growth of teak. On the limestone of the Thaungyin valley, the Ruby Mines district, the Madaya valley and parts of the Chindwin drainage of Burma, teak flourishes well where the rock has disintegrated to form a deep loam, though on hard limestone with a shallow soil the growth is poor. Teak occurs on limestone in parts of the Central Provinces and locally in North Kanara. The great trap areas of the Indian Peninsula are extensively covered with teak. As a general rule the soil is of no great depth, and although teak is often remarkably plentiful, it is of small size ; only in valleys and on lower slopes, where there is some depth of soil, does the tree attain fair dimensions in the trap areas. Teak as a rule avoids laterite, and where found on this rock it is invariably stunted ; only where the laterite is highly disintegrated and mixed with other rocks does it attain any size.

LOCAL OCCURRENCE AND TYPES OF FOREST. *Burma.* The general limits of teak in Burma have already been given. The tree does not extend to (1) Arakan, South Tenasserim, and the extreme north of Upper Burma, where, apart from other possible reasons for its absence, the heavy rainfall frequently renders the forest evergreen in type ; (2) low-lying savannah lands, tidal regions of the delta, many laterite areas, and other places which are unsuitable for its growth ; (3) elevations higher than about 3,100 ft. ; (4) the drier parts of the dry zone of Upper Burma. It occurs round the fringes of the dry zone, but does not extend into regions where the rainfall is much below 40 in. ; outlying patches of teak within the dry zone occur on the lower slopes and round the base of Popa mountain in the Myingyan district, but here the rainfall is heavier than in the drier tracts around, and the soil is composed of fertile volcanic débris. Elsewhere teak occurs in suitable localities throughout the greater part of the province, though there are considerable tracts where it is absent.

In 1917 the total area of teak-bearing forest in Burma was roughly estimated to be 35,000 square miles. The majority of these forests are situated on hilly or undulating ground, but there are some important forests situated on flat ground of alluvial origin. Perhaps the most important stretch of teak-

bearing forest in the province is on the Pegu Yoma, a range of hills composed of tertiary sandstone and shale and forming for the greater part of its extent the watershed between the Irrawaddy and Sittang rivers: these forests form an unbroken stretch more than 200 miles in length and averaging about 30 miles in breadth. There are also extensive teak tracts in the drainages of the Salween, particularly in the Southern Shan States, of the Thaungyin, the Chindwin and its tributaries, and the upper Irrawaddy, including the Shweli, Madaya, and other important drainages. Teak forests of varying extent occur also on the eastern slopes of the Arakan Yoma, in the hills east of the Sittang river, and in the Ataran drainage. The Myitngè river drainage contains several teak areas, partly in the Northern Shan States and partly in the Yeyaman tract of the Kyauksè district.

Teak occurs normally in mixed deciduous forests, but occasionally teak trees are found standing in dense evergreen forest (see Fig. 265). These trees are often of very large size, testifying to the fertility of the soil. Such cases are examples of progressive succession from a deciduous to an evergreen type, for the teak is incapable of regenerating in dense evergreen forest, and must have established itself when the forest was of a deciduous type. The gradual encroachment of evergreen species in moist deciduous forest can often be observed, particularly in areas where fire-protection has been introduced, and in some cases teak trees may be found recently killed by the suppression of faster-growing invasive species.

The teak-bearing forests of Burma may be classified into numerous sub-types, but the more important of these can be referred to one of two main types which Kurz designated 'upper mixed' and 'lower mixed' respectively, terms which have been adopted generally and are well understood. The general distinction between these two main types is as follows: (1) upper mixed forest (Fig. 266) as a rule occupies hilly or undulating country, and is usually characterized by the prevalence of bamboos; (2) lower mixed forest (Fig. 267) occurs on lower ground, which is flat or nearly so, and is usually alluvial, white bamboos are either absent or not well distributed. Both these types are essentially deciduous, but in their moister parts they tend to merge into evergreen, while the two types may merge imperceptibly into each other, so that a sharp line cannot always be drawn between them. The upper mixed forests are by far the more extensive, and may be regarded as the true home of the teak; some of the richest teak areas, however, are to be found in lower mixed forest.

The upper mixed forests may be divided into two chief sub-types, (a) dry and (b) moist, according to the comparative dryness or moistness of the forest growth, of which the best indicators are the bamboos, which are such an important constituent of the crop. A sharp distinction cannot always be drawn between these two sub-types, more especially since the majority of the tree species associated with the teak occur in both.

In dry upper mixed forest the typical bamboo is *Dendrocalamus strictus*, but some of the bamboos of the moist forest, notably *Cephalostachyum pergracile*, often in stunted form, extend into dry forest. *Bambusa Tulda* occurs in both, and *Thyrsostachys Oliveri* is found in somewhat dry types as well as in fairly moist types in Upper Burma. Dry upper mixed forest may either

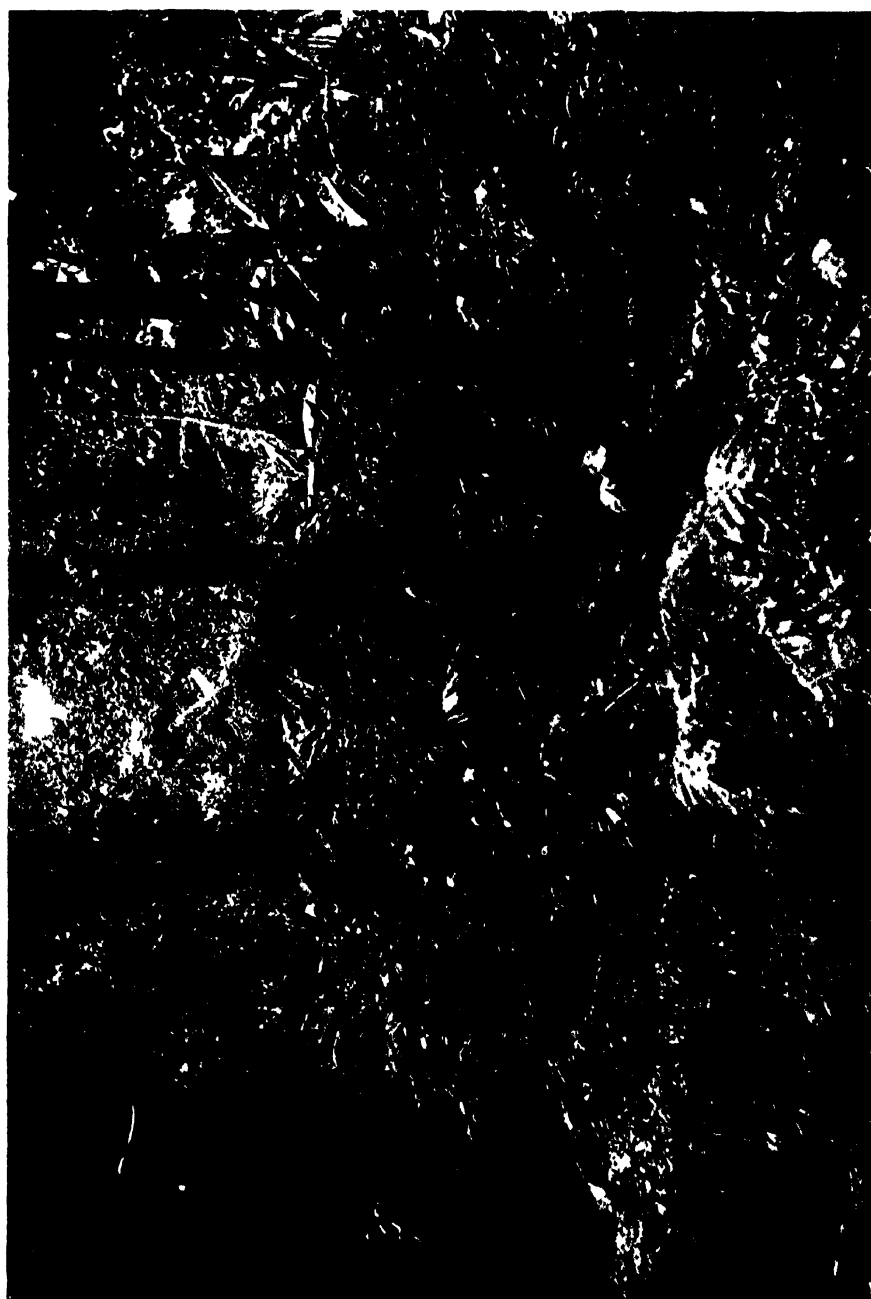


Fig. 265 Teak in evergreen forest Mogaung Upper Burma



FIG. 266. Teak in upper mixed forest, Bhamo district, Upper Burma : the bamboo is young *Cephalostachyum pergracile*.

occur in unbroken stretches of considerable extent or be confined to the crests and upper slopes of ridges and spurs, the lower slopes of which are occupied by moist forest. As a rule teak does not attain such large dimensions in dry as in moist forest, but it reproduces itself more freely in the former. The most typical associates of teak in dry forest are *Xylia dolabriformis*, *Terminalia tomentosa*, *T. Chebula*, *Acacia Catechu*, *Pterocarpus macrocarpus*, *Homalium tomentosum*, *Shorea obtusa*, *Pentacme suavis*, *Dalbergia cultrata*, *Bombax insigne*, *Sterculia* spp., *Premna tomentosa*, as well as many other species.

A particular form of somewhat dry forest is that known by the Burmans as *thitkyin*, in which bamboos are scarce or absent and there is often an undergrowth of thorny twiners; the most characteristic trees are teak, *Xylia dolabriformis*, *Terminalia tomentosa*, *Homalium tomentosum*, and *Lagerstroemia Flos-Reginae*, and there is sometimes a dense advance growth of young *Xylia*.

In moist upper mixed forest the prevailing bamboos vary with locality. Throughout the Pegu Yoma and in certain other tracts the most typical species are *Bambusa polymorpha* and *Cephalostachyum pergracile* in its more luxuriant form; the latter has a wide range in Burma. Locally common is *Oxytenanthera albociliata*, often on sandy soil. In moist valleys of the Pegu Yoma, *Dendrocalamus longispathus* is common, and where the moist forest merges into evergreen forest dense masses of *Teinostachyum Helferi* cover the ground. In the northern parts of Upper Burma among the commoner bamboos of the moist mixed forest are *Dendrocalamus Brandisii*, *D. Hamiltonii*, and *D. membranaceus*, with *Cephalostachyum pergracile* plentiful in some localities.

The commoner tree species associated with teak in the moist upper mixed forests are *Xylia dolabriformis*, *Lagerstroemia Flos-Reginae*, *L. tomentosa*, *Anogeissus acuminata*, *Terminalia belerica*, *T. pyrifolia*, *Homalium tomentosum*, *Adina cordifolia*, *A. sessilifolia*, *Stephegyne diversifolia*, *Vitex glabrata*, *Bombax insigne*, *Eugenia* spp., and where the forest merges into evergreen, *Dipterocarpus alatus*.

In the lower mixed deciduous forests teak is associated with *Xylia dolabriformis*, *Lagerstroemia Flos-Reginae*, *L. tomentosa*, *Dipterocarpus alatus*, *Berrya Ammonilla*, *Terminalia tomentosa*, *T. pyrifolia*, *T. belerica*, *T. Chebula*, *Adina cordifolia*, *A. sessilifolia*, *Stephegyne diversifolia*, *Odina Wodier*, *Spondias mangifera*, *Eugenia Jambolana*, *Eriolaena Candollei*, *Careya arborea*, *Vitex glabrata*, *Dillenia pentagyna*, *Miliusa velutina*, *Diospyros ehretioides*, *Dalbergia cultrata*, *D. purpurea*, *Kydia calycina*, *Pterospermum semisagittatum*, *Phyllanthus Emblica*, *Anogeissus acuminata*, *Bridelia retusa*, *Schleichera trijuga*, and many others. In these forests teak avoids the badly drained areas, but where the drainage is good it may become very plentiful and may reach large dimensions.

Particularly rich teak forests of the lower mixed type are the Kangyi and Satpôk reserves in the Tharrawaddy district, both of which are outlying forests on the alluvial plain of the Myitmaka river. To this type may be referred the interesting forest of Mohnyin in the Katha district of Upper Burma (see Fig. 264). This forest is situated on flat or nearly flat ground on deep alluvial soil. Over part of the area teak forms the bulk of the growing stock, and in places is practically pure, and the trees reach very large dimensions. The peculiarity about this forest, apart from the high percentage of

teak it contains, is that the trees are mainly of large dimensions, the proportion of small trees being very deficient; natural reproduction is almost entirely wanting until special measures, which are described later, are taken to stimulate it. Bamboos are absent over much of the area; the chief companions of the teak are *Gmelina arborea*, *Anogeissus acuminata*, and *Careya arborea*. Although the teak trees attain large size the timber is not of the best quality, being much riddled by the bee-hole borer (*Duomitus ceramicus*, Wlk.).

In some localities, notably in the Ruby Mines district, teak occurs in belts or pockets which follow the courses of streams, large stretches of intervening country being covered with *indaing* or other types of forest devoid of teak. The teak confines itself to the alluvial flats or other fertile ground in the neighbourhood of the watercourses. Throughout Burma, in forest both of the upper and of the lower mixed types, teak is very commonly found, sometimes in gregarious form, on well-drained alluvial flats of varying size, on the fertile loam of which it may attain large dimensions. Bamboos are often absent in such places, or if they are present the commonest species is *Bambusa Tulda*. Teak is sometimes found in *indaing* forest on laterite, but in this type it is invariably stunted.

As a general rule teak forms a comparatively small proportion of the growing stock in the forests of Burma, the trees being scattered singly or in groups among a large number of other species. Some years ago I made an examination of the numerous statistics contained in the various working plans which have been compiled for the teak forests, and published the results.¹ The figures yielded—including those furnished by the Mosit reserve in Bhamo, the working plan of which has been issued since—show that over the teak-bearing area of whole forests, that is, whole working circles and not selected areas rich in teak, the average number of teak trees 6 ft. or over in girth per 100 acres is 100 or more in respect of fourteen forests hitherto enumerated, aggregating 972 square miles of teak-bearing forest; of these the Mohnyin forest heads the list with 241 such trees per 100 acres. Only four of these forests have 100 or more teak trees 7 ft. in girth and over per 100 acres.

Considering next those forests which are rich in sound teak trees 3 ft. and over in girth, it is interesting to note that the three richest forests are situated on flat alluvial ground. The three forests in question are:

1. Mohnyin (Katha division), 707 trees per 100 acres.
2. Satpók (Tharrawaddy division), 455 trees per 100 acres.
3. Kangyi (Zigôn division), 441 trees per 100 acres.

Satpók and Kangyi are typical lower mixed forests. Next in order of richness come two typical upper mixed forests of the Pegu Yoma, namely Bondaung (Toungoo) with 409 trees, and Kadinbilin (Tharrawaddy) with 408 trees. No fewer than nine forests have totals of between 300 and 400 sound teak trees 3 ft. and over in girth per 100 acres, and of these all but one are situated in the Pegu Yoma.

As regards the percentage of teak in the total growing stock in teak-bearing forest, in the twelve richest forests in which enumerations of all species have been carried out, the percentage of sound teak trees 3 ft. in girth and

¹ A Note on some Statistical and other Information regarding the Teak Forests of Burma. Ind. For. Records, vol. iii, pt. i, 1911.

over varies from 15 to 33, the two richest forests being situated in the Zigôn forest division ; these are Bawbin with 33 per cent., and Kangyi with 29 per cent., the former being of the upper and the latter of the lower mixed type. These figures, however, do not include the Mohnyin forest, in which only teak was enumerated ; this forest probably contains a much larger percentage of teak than any other. The lowest percentage of teak 3 ft. and over in girth in true teak forests hitherto enumerated is 6, in the Gwethe and Saing working circles of Toungoo.

Indian Peninsula, general distribution. The distribution and types of teak forest in the Indian Peninsula are determined mainly by rainfall and geological formation with resulting soil. The great majority of the teak areas are situated on one of two great systems of rocks : (1) the Deccan trap, which stretches from about 25° N. lat. southwards with occasional interruptions to about 16° N. lat., embracing parts of Central India and the Central Provinces, the greater part of Berar, the whole of the northern part of Bombay as far south as Belgaum, and the western part of Hyderabad ; (2) the crystalline rocks (granite, gneiss, schist, &c.) which occur in Bundelkhand, in several parts of the Central Provinces, in the eastern part of Hyderabad, along the Western Ghats and throughout the greater part of the Madras Presidency. Broadly speaking, there is a marked difference in the types of teak forest found on these two geological formations. On the trap areas, where the soil is often very superficial, the teak is usually of small size but occurs in great abundance, often forming the bulk of the growing stock and even occurring pure over considerable areas. To some extent this is due to artificial causes, in that teak has been able to survive better than its companions the lopping, hacking, grazing, and burning to which many of the forest tracts have for long been subjected ; in some cases also teak owes its prevalence to the fact that as a ' royal tree ' it has received special protection in the past. On the crystalline areas, although the teak trees are as a rule more scattered than they are on trap, they reach considerably larger dimensions where the rainfall is favourable.

United Provinces. In the Jhansi district of the United Provinces teak occurs on gneiss and quartzite, and is confined to areas within a few miles of the larger rivers. It is found in the small forest of Sairwas, where it forms the greater part of the crop, in the protected forests of Talbehat, and occasionally on the bank of the Betwa river. The rainfall in these tracts is under 40 in., and the teak is of small size.

Central Provinces and Berar. In the Central Provinces and Berar teak occurs to a greater or less extent in Jubbulpore, Damoh, Saugor, Hoshangabad, Seoni, Chindwara, Nagpur, Wardha, Chanda, Balaghat, Bilaspur, Raipur, Buldana, Betul, and Amraoti (Melghat), and possibly to a small extent in other localities. In Bilaspur, Balaghat, and Raipur it is very local, occurring chiefly on alluvial ground near streams. Within its region the rainfall varies from under 40 in. to about 65 in., except in the Bori forest of the Hoshangabad district, where it is between 75 and 80 in. Teak occurs on a variety of geological formations, notably trap, limestone, gneiss, mica schist, sandstone, conglomerate, shale, and clay. It is usually absent from the quartzite plateaux, and although occasionally found on laterite, the growth is poor ; it also avoids

black cotton soil. On trap areas teak is often very plentiful, though of small size. In some localities it attains a fair size on the Vindhyan limestone and sandstone or on alluvial ground near rivers. Teak is not ordinarily found with sal, but occasionally the two occur mixed, for example in the Bilaspur district, where there is a small area of teak mixed with sal poles near Deosara in the West Lormi range. The requirements of the two species differ, teak seeking good subsoil drainage combined with a fair rainfall, and sal seeking the more hygroscopic soils.

Teak is one of the constituents of the mixed deciduous forests which are so typical of the Central Provinces. Its chief companions are *Terminalia tomentosa*, *T. belerica*, *Lagerstroemia parviflora*, *Ougeinia dalbergioides*, *Anogeissus latifolia*, *Dalbergia latifolia*, *D. paniculata*, *Pterocarpus Marsupium*, *Diospyros Melanoxyton*, *Acacia Catechu*, *Chloroxyton Swietenia*, *Soyimida febrifuga*, *Schleichera trijuga*, *Schrebera swietenoides*, *Gmelina arborea*, *Cleistanthus collinus*, *Odina Wodier*, *Cassia Fistula*, *Bridelia retusa*, *Adina cordifolia*, *Stephegyne parvifolia*, *Butea frondosa*, *Bassia latifolia*, *Phyllanthus Emblica*, *Buchanania latifolia*, *Xylia xylocarpa* (in Chanda), and *Boswellia serrata* (in dry places and on ridges). The prevailing bamboo in teak-bearing forest is *Dendrocalamus strictus*, but occasionally *Bambusa arundinacea* is found on alluvial flats by rivers. The type and quality of the forest, and the actual companions found with the teak, vary according to local conditions. In the great majority of cases the teak is of comparatively small size, and it has often suffered from past maltreatment in the shape of lopping, grazing, and burning, in consequence of which many trees are unsound or misshapen.

The largest teak in the Central Provinces is produced in South Chanda, in which the most important forests are those of Allapilli in the Ahiri range, forming a compact block about 73 square miles in area and situated about 70 miles south of Chanda. The north-west and central parts of this tract are flat or undulating, the remainder being hilly, the Bhimaram hills in the south-west rising to 1,600 ft. above sea-level. The rock is metamorphic, chiefly granitic; the soil is a rich light loam, but is shallow and rocky on the hill ridges. The rainfall is about 50 in. The forests of the Bhimaram hills are characterized by a plentiful growth of bamboo (*Dendrocalamus strictus*). Teak is the most plentiful tree species, the forest consisting in many places of large teak trees standing between bamboo clumps, with scattered individuals of *Dalbergia latifolia*, *Pterocarpus Marsupium*, and *Stephegyne parvifolia*, while *Schleichera trijuga* is common in the valleys. At the base of the hills and in the valleys the forest is more varied, the teak being associated with *Terminalia tomentosa*, *Stephegyne parvifolia*, *Adina cordifolia*, *Diospyros Melanoxyton*, *Anogeissus latifolia*, *Odina Wodier*, *Xylia xylocarpa*, *Holarrhena antidysenterica*, *Butea frondosa*, *Cleistanthus collinus*, and others. These species extend to the Bhimaram plains forests, where teak greatly predominates, and to the Mirkullu block, though the hilly portions of the latter are occupied by a very dense growth of bamboo, the result of former shifting cultivation.

Another interesting teak forest in the Central Provinces is the Bori forest in the Hoshangabad district. This forest is situated in a deep valley at an average elevation of 1,450 ft. above sea-level, through which runs the Bori river; this valley is enclosed on the north by a scarped ridge rising to 3,777 ft.,

and on the south by several minor ridges rising to 1,900 ft. above sea-level. The rocks are partly trap, partly massive sandstones of the upper Gondwanas, and partly soft sandstones, clays, and shales of the lower Gondwanas. The soils resulting from these rocks are often intermingled, the result being favourable to forest growth, though the teak is most abundant and of best growth where trap predominates. An important factor is the rainfall, which is between 75 and 80 in., and is considerably higher than in any of the neighbouring parts of the Peninsula. Teak is the predominant tree, especially on alluvial ground along river-banks, where it may form as much as 90 per cent. of the crop. The chief associate species are *Ougeinia dalbergioides*, *Terminalia tomentosa*, *Diospyros Melanoxylon*, *Lagerstroemia parviflora*, *Anogeissus latifolia*, *Pterocarpus Marsupium*, *Dalbergia latifolia*, and many of the other common trees of the Central Provinces. Bamboos (*Dendrocalamus strictus*) are also plentiful. Teak is capable of reaching very fair dimensions, and coppice-shoots show remarkable growth, attaining a height of 100 ft. and a girth of 6 ft.

Bombay. The most important teak forests of the Bombay Presidency are those of North Kanara, where under the influence of a heavy rainfall and favourable soil the trees attain large dimensions. The rocks are chiefly crystalline (granite, gneiss, schist, limestone, quartzite, &c.), with occasional trap or sandstone and shale, and the soil is often a deep rich loam. Laterite is frequent, but the teak avoids pure laterite soils. The best teak areas of the Western Ghats and below-*ghat* tracts of North Kanara are in the regions of heavy rainfall, that is, where the rainfall is over 60 in., and may reach 150 in. or more. Here the teak reaches large dimensions on well-drained slopes such as those of the Kalinaddi and Gangawuli river drainages.

Teak occurs only in mixed deciduous forests, and although occasional trees are found standing in evergreen forest this, as in Burma, indicates recent encroachment of evergreen species in former forest of a deciduous type. In the Kanara high forests, teak is a scattered tree, forming a comparatively small proportion of the growing stock. Farther inland, where the rainfall is less, the teak diminishes in size but increases in relative quantity; thus the eastern parts of Kanara, and the adjoining forest tracts of Belgaum and Dharwar, where the rainfall varies from 35 to 60 in., are the regions of teak pole forests. The chief companions of the teak in the forests of Kanara are *Terminalia tomentosa*, *T. paniculata*, *T. belerica*, *Lagerstroemia lanceolata*, *L. parviflora*, *Dalbergia latifolia*, *Pterocarpus Marsupium*, *Xylia xylocarpa*, *Adina cordifolia*, *Stephegyne parvifolia*, *Grewia tiliaefolia*, *Schleichera trijuga*, *Stereospermum xylocarpum*, *Anogeissus latifolia*, *Saccopetalum tomentosum*, *Dillenia pentagyna*, and *Careya arborea*. The bamboos are *Bambusa arundinacea* on the lower slopes and in the valleys, *Dendrocalamus strictus*, and *Oxytenanthera monostigma*, the last-named often forming on the upper slopes a dense undergrowth which hinders natural reproduction.

Outside North Kanara, Belgaum, and Dharwar, teak is found over a considerable portion of the great trap area extending from Surat and Khandesh in the north to the northern parts of Kanara and Belgaum in the south, as well as on the gneiss, schist, sandstone, and quartzite of the Panch Mahals. In the Khandesh Akrani teak ascends to 3,700 ft. Throughout the great bulk of the trap area the teak is of comparatively small size, but, as elsewhere on

trap formation, it forms as a rule a large percentage of the growing stock, sometimes occurring practically pure over considerable areas. The rainfall over most of the trap areas of Bombay varies from under 30 in. to about 70 in., but in the *ghat* regions of Thana and Nasik it is in places over 100 in. Where the rainfall is small the growth is extremely poor, and reproduction is largely from shoots sent up from stools and old thickened root-stocks; here the teak suffers periodically from drought. Even where the rainfall is heavy the soil is often shallow and rocky and the trees do not reach large dimensions, though occasionally in valleys and ravines where there is some depth of soil, fair growth is attained. In the Dangs of Surat and the Khandesh Akrani teak attains a larger size than in most parts of the trap area, but the larger trees are usually unsound owing to past maltreatment.

The companions of the teak in these forests are much the same as those occurring in most of the Central Provinces teak forests, and include *Terminalia tomentosa*, *T. belerica*, *T. Chebula*, *Lagerstroemia parviflora*, *Adina cordifolia*, *Stephegyne parvifolia*, *Grewia tiliaefolia*, *Pterocarpus Marsupium*, *Dalbergia latifolia*, *Ougeinia dalbergioides*, *Phyllanthus Emblica*, *Cassia Fistula*, *Acacia Catechu*, *Diospyros Melanoxydon*, *Butea frondosa*, *Bridelia retusa*, *Odina Wodier*, *Soyimida febrifuga*, *Erythrina suberosa*, *Schleichera trijuga* (chiefly near water-courses), and *Boswellia serrata* (in dry places). The bamboos, where present, are *Dendrocalamus strictus* and, on the more fertile ground or where the rainfall is heavy, *Bambusa arundinacea*.

Southern India. The most important natural teak areas of southern India are in North and South Malabar, particularly in the Wynaad, the Anamalai hills, Coorg, the south-western part of Mysore, and Travancore, that is, in the south-westerly part of the Peninsula. The rocks are for the most part metamorphic (granite, gneiss, and schist), and the rainfall in the best teak areas is chiefly between 60 and 150 in., but is more in places. Teak here occurs in mixed deciduous forest; the companion species are much the same as those of North Kanara, and include *Terminalia tomentosa*, *T. belerica*, *T. paniculata*, *Dalbergia latifolia*, *Lagerstroemia lanceolata*, *Pterocarpus Marsupium*, *Grewia tiliaefolia*, *Schleichera trijuga*, *Anogeissus latifolia*, *Adina cordifolia*, *Stephegyne parvifolia*, *Stereospermum xylocarpum*, *Careya arborea*, *Bombax malabaricum*, and *Gmelina arborea*. *Xylia xylocarpa* occurs below the *ghats*, sometimes associated with teak. The chief bamboo is *Bambusa arundinacea*, with *Dendrocalamus strictus* on drier slopes.

In Malabar teak flourishes and reaches large dimensions, both in the Wynaad, at elevations of over 2,000 ft., with a rainfall of about 80 to 140 in. and at lower elevations below the *ghats*, where the rainfall is heavier. The Nilambur valley of South Malabar is celebrated for its extensive and remarkably successful teak plantations, commenced in 1844 and continued to the present day. In the Anamalais teak grows to a large size on fertile loam resulting from the decomposition of gneiss. The teak forests are of a somewhat moist type, the chief associate species being those just mentioned, and there is often a dense herbaceous undergrowth which prevents teak reproduction.

The forests of Coorg fall into two main tracts—the eastern forests, at an altitude of 2,600 to 4,488 ft., with a rainfall varying from 124 in. at Mercara

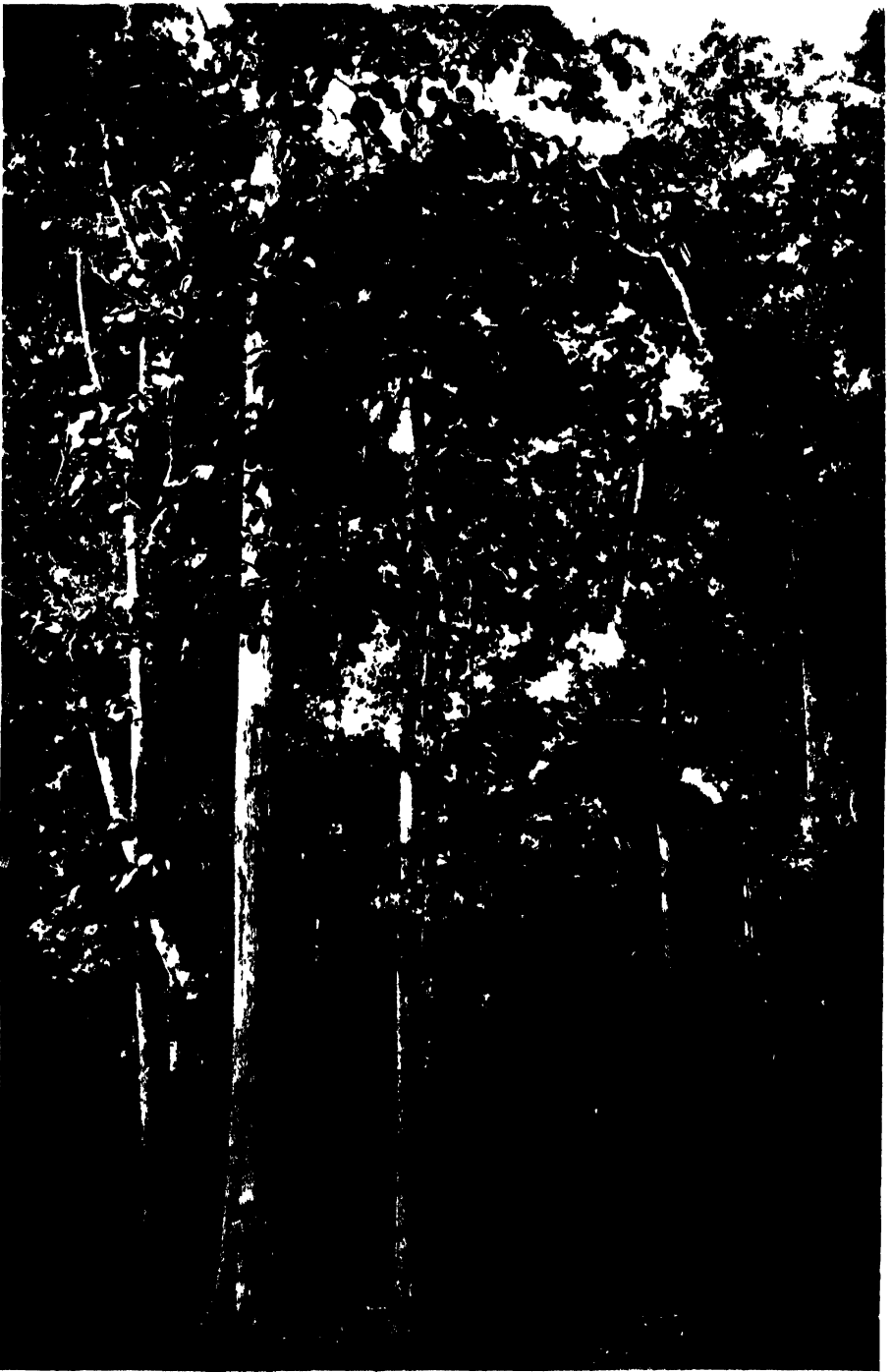


FIG. 267. Teak in lower mixed forest, Pyinmana, Upper Burma : on right of large teak tree is a *Dillenia* tree.

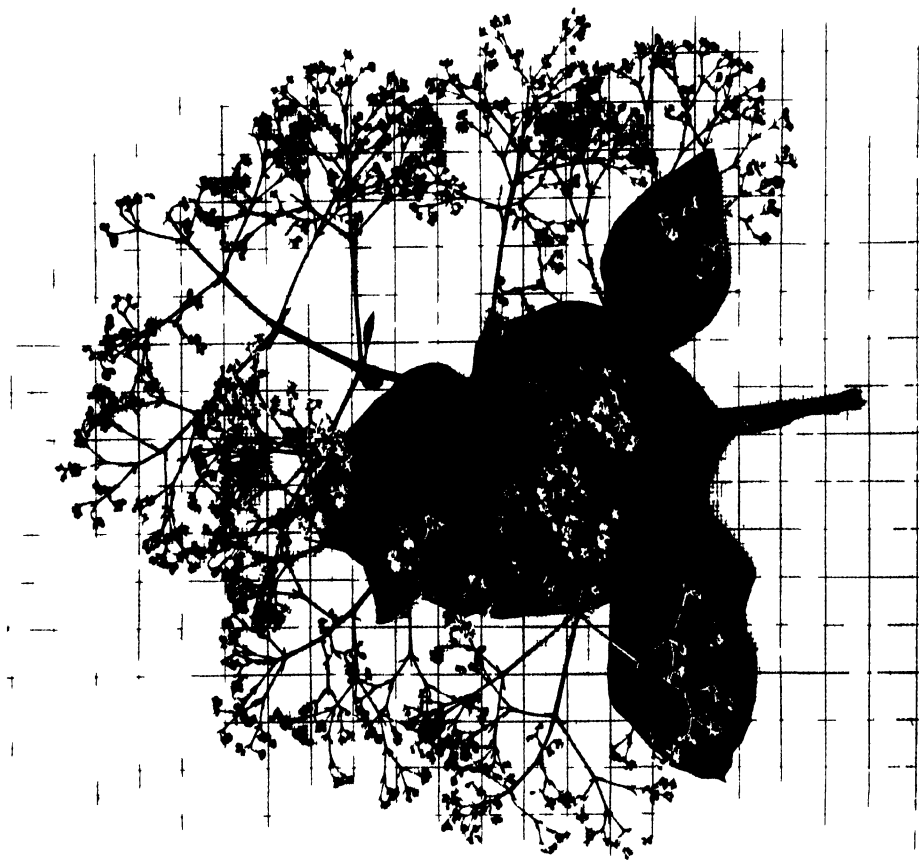


FIG 268 *Tectonia grandis*, inflorescence Squares show inches, and tenths.

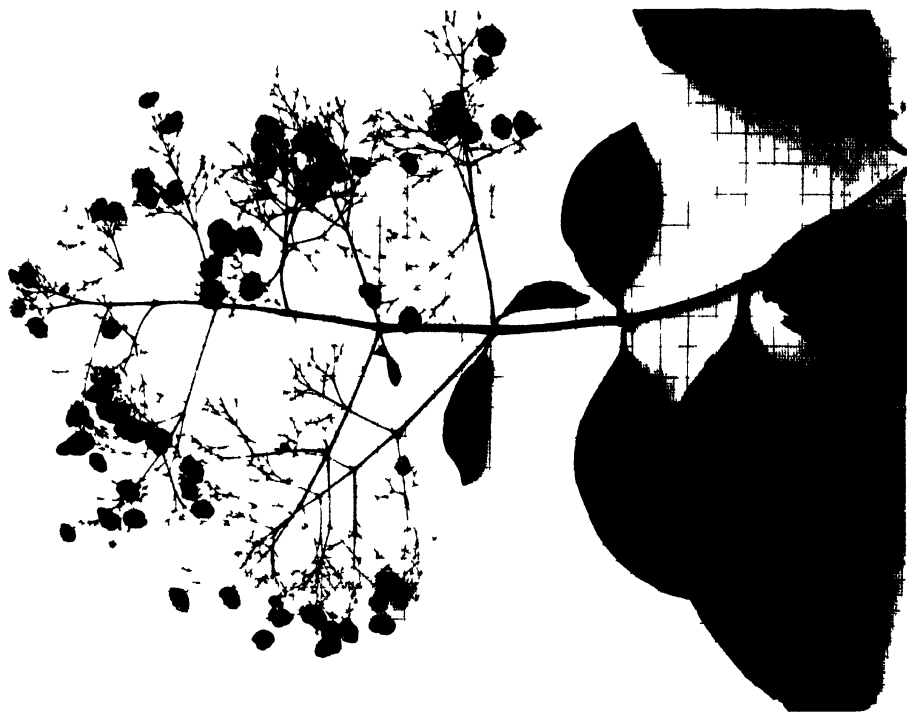


FIG 269 *Tectonia grandis*, fruiting panicle Squares show inches, and tenths.

to 42 in. at Fraserpet, and the *ghat* forests, situated on the slopes of the Western Ghats and in the tracts below, where the rainfall is probably as much as 300 in. or more in places. The rock is chiefly gneiss, which is covered as a rule with a considerable depth of soil; laterite is found in places, but the teak avoids pure laterite. The eastern forests may be roughly divided into two zones, the dry eastern or teak zone and the western or moist zone. In the former teak is plentiful, but in the drier parts to the east the forest is open and the growth is poorer than it is farther west; in the south-eastern forests the growth is better. The western zone is characterized by a luxuriant growth of *Bambusa arundinacea*; the forest is well stocked with numerous tree species of good growth, but teak is comparatively rare, though existing plantations indicate that the locality is well suited to its growth. The *ghat* forests are mainly evergreen, and are not teak-bearing.

In Travancore teak grows at various elevations up to 3,000 ft., though at the higher levels it does not thrive. It is found on sandstone, granite, and limestone, as well as on alluvial ground along rivers. The best teak is found on the lower slopes of hills up to 2,000 ft. elevation; the Idiyera valley was at one time celebrated for the size and quantity of its teak, but extensive working, dating from 100 years ago or more, has depleted this and other favourable localities. In Travancore, as elsewhere, teak grows in mixed deciduous forests, its chief companions being those noted above for south-west India in general. The common bamboo is *Bambusa arundinacea*, while in the Idiyera valley the teak is found growing among thickets of the reed-like bamboo, *Ochlandra travancorica*, Benth. In Travancore the teak grows best where the rainfall is 100 in. or more. In the drier parts of the state, particularly in the extreme south, it is of small size, but grows in fair quantity, often forming the greater part of the growing stock.

Among other teak localities in the Madras Presidency may be mentioned Coimbatore (apart from the Anamalai hills) chiefly on gneiss, Tinnevely on granite and schist, South Cuddapah up to 3,900 ft., the Yerramalais of West Kurnool, where the rainfall is only about 25 in., and teak occurs locally in stunted form, chiefly on shale, and along the Godavari river. The Godavari forests are situated partly on hilly and partly on level ground; the soil is fertile and is capable of producing fair-sized timber, but the forests have suffered from past over-felling and from shifting cultivation. The teak wood from these forests is figured and ornamental, and is prized for furniture and cabinet-making. Among the chief associates of the teak in the Godavari forests are *Terminalia tomentosa*, *T. Chebula*, *Xylia xylocarpa*, *Dalbergia latifolia*, *Pterocarpus Marsupium*, *Lagerstroemia parviflora*, *Adina cordifolia*, *Anogeissus latifolia*, *Soymida febrifuga*, *Chloroxylon Swietenia*, *Diospyros Melanoxylon*, and *Cleistanthus collinus*.

LEAF-SHEDDING, FLOWERING, AND FRUITING. In dry situations and seasons the leaves fall from November to January, while in moist localities the tree may remain in leaf until March or even later. As a rule the trees are leafless throughout the greater part of the hot season. The new leaves ordinarily appear from April to June according to locality and season; in wet seasons they sprout early, while in abnormally dry seasons the trees remain leafless longer than usual.

The large terminal panicles of small white flowers (Fig. 268) appear during the rainy season, as a rule from June to August or September according to season and locality, but in abnormally wet seasons they may begin to appear as early as April, as they did in Berar in 1915 as a result of frequent showers early in the year. During the rainy season the teak trees are conspicuous from a distance with their masses of white inflorescences. Mr. E. Marsden states that he observed the teak in full flower in the Tinnevely district, Madras, in January 1917, and that this is apparently usual.

The fruits ripen from November to January and fall gradually, some remaining on the tree through part of the hot season. The fruit is a hard, bony, irregularly globose nut (Fig. 270, *a*), somewhat pointed at the apex, enclosed in a thick, felty, light brown covering, usually 0.4–0.6 in. in diameter, but varying much in size, containing one to three, rarely four, seeds. The nut is enclosed in the inflated bladder-like calyx, 0.8–1.5 in. in diameter. Throughout the cold season the feathery erect fruiting panicles (Fig. 269) are conspicuous on the trees. The fruit may be conveniently collected by clearing the ground under the trees in January and February and sweeping up the fruits every few days; the fruits may, if necessary, be lightly beaten off the trees with sticks. For convenience in storage and transport it is advisable to remove the bladder-like calyx. This can be done by half filling a bag with the fruits and vigorously rubbing and shaking it, after which the remains of the calyces can be separated from the nuts by winnowing. The nuts vary much in weight. In samples from Burma the number varied from 570 to 850 per lb., while in samples from the Central Provinces it varied from 900 to 1,400 per lb.

The teak seeds well almost every year, though occasional poor seed-years occur. The seed-crop may be partially destroyed by storms between the time of flowering and fruiting. Insects are sometimes responsible for the destruction of much of the seed-crop. Fertile seed begins to be produced at a comparatively early age. A plantation formed in 1873–4 at Ramgarh in the Gorakhpur district, United Provinces, commenced regenerating naturally when less than twenty years of age. Coppice-shoots flower and fruit abnormally early. Seed from coppice nine years old, collected in Saugor, Central Provinces, and tested by the Forest Botanist at Dehra Dun in 1908, germinated and produced healthy seedlings. This disposes of the idea that seed from coppice shoots is necessarily unfertile. Mr. G. M. Ryan,¹ however, states that germination tests with seed from coppice-shoots up to fifteen years old in Thana, Bombay, were unsuccessful. Old trees are capable of producing fertile seed: in Burma seed from large trees 10 ft. in girth and over has been tested on at least three different occasions and found to be quite fertile.

Individual tests reveal considerable differences in the percentage of fertility of teak seed, but as a rule the percentage is high in well-selected seed. The seed often fails to germinate the first year, particularly if sown late, and may lie dormant in the ground for one or more years before germinating. Seed stored for a year is usually found to germinate more freely than fresh seed. Various methods of hastening germination are described below under 'artificial reproduction'. The vitality of teak seed is remarkable. Two instances may be quoted in which seed has lain dormant for many years, retaining its fertility.

¹ Ind. Forester, xxx (1904), p. 456.



FIG. 270. *Ictona grandis*- SEEDLING $\times \frac{5}{8}$

a Nut b - g—Germination stages f - j—Development of seedling during first season

The first is the case of the Mohnyin forest in Katha, Upper Burma, situated on flat ground and consisting in parts of almost pure teak of large size but with no reproduction present. Some years ago experiments were undertaken to induce natural reproduction, among other measures tried being the clearing of undergrowth and the clean sweeping of the ground; this resulted in the appearance of dense masses of teak seedlings sprung from seed which had lain dormant in the ground, and which must have accumulated for years before producing seedlings in such quantities. In a portion of the Bilumyo forest near and of the same type as Mohnyin, all teak seed-bearers were girdled in 1911, and in 1915 the forest growth was cleared and burnt; this was followed by the plentiful appearance of teak seedlings from seed which must have lain dormant in the ground for at least four years.

The second instance is one recorded by Mr. A. W. Lushington¹ in the forests of the Nallamalais of Kurnool. Here from 1901 onwards clear-fellings made in a type of forest devoid of teak trees resulted in plentiful natural reproduction of teak: this is attributed to the fact that in the sixties of last century or later teak was abundant in these forests, whereas in the eighties or nineties a totally different type of forest arose by which the teak was temporarily ousted, and when from 1901 onwards this forest was cut, teak sprang up in abundance from seed which must have lain dormant in the ground for many years.

GERMINATION (Fig. 270, *b-g*). Epigeous. The nut splits open on one or two sides, or sometimes on three or even four sides, the side pieces separating from the central axis of the nut like valves. Through the openings thus caused the radicles first emerge and descend, the cotyledons soon making their way upwards through the cracks, leaving the testas within the nut. As the plant emerges the valves soon fall away from the central portion of the nut. One nut usually produces one or two seedlings, but occasionally as many as three or even four seedlings may be produced.

THE SEEDLING (Fig. 270).

Roots: primary root long, thick, terete, tapering, tomentose, whitish and delicate at first, becoming light brown and woody later. lateral roots numerous, moderately long, at first delicate, white, pubescent, afterwards fibrous. *Hypocotyl* distinct from root, 0.5-1 in. long, compressed, white turning green, tomentose and covered with minute dark red glandular dots. *Cotyledons*: petiole 0.1-0.25 in. long, channelled above, light green, tomentose, covered with minute dark red glandular dots: lamina 0.45-0.6 in. by 0.3-0.5 in., foliaceous, fleshy, broadly elliptical ovate, entire, apex emarginate, base cordate or truncate, convex and bright green above, concave and paler green beneath, minutely tomentose and covered on both surfaces with minute dark red glandular dots which turn black later, midrib depressed, basal lateral veins two, somewhat obscure. *Stem* erect, at first terete or slightly compressed, soon becoming quadrangular, green, tomentose, covered with glandular dots, at first dark red, soon turning black. *Leaves* simple, opposite decussate, exstipulate. Petiole 0.1-0.5 in. Lamina 1-12 in. or more by 0.4-10 in., elliptical ovate or obovate, acute or obtuse, base tapering, serrate or crenate, hispid above, coarsely pubescent beneath, both surfaces, particularly the lower, covered with glandular dots at first dark red, soon becoming black; venation prominently reticulate, the veins depressed on upper, raised on lower surface.

¹ Ind. Forester, xxxii (1907), p. 409.

Fig. 271 shows seedlings in various stages up to about two months old. During the first year the leaves remain comparatively small except in the case of vigorous seedlings which have grown under favourable conditions ; these develop large leaves which may reach a length of over 1 ft. Fig. 272 shows a vigorous seedling during the first season. In the Nilambur plantations transplanted seedlings which are regularly weeded attain an average height of 6 ft. by the end of the first year on soils of good quality, the principal growth taking place not during the rainy season but as soon as it is over. Under less favourable conditions a height of not more than a few inches is attained during the first season. Healthy seedlings produce a stout taproot which may attain a length of 12 in. or more during the first season and 2-3 ft. or more by the end of the second season. Seedlings are leafless during part of the hot season.

Teak seedlings are decidedly sensitive to drought and to frost, particularly during the first year, when they are frequently killed outright. During the second and subsequent years frost does less permanent injury, and plants, if affected, have a better chance of recovery from the base. In the drier parts of the Peninsula drought is a common cause of death among seedlings, and it is of the greatest importance to secure early germination and vigorous development during the first rainy season, in order to enable the young plants to survive the subsequent dry weather. In dry localities the stems of seedlings are frequently killed back by drought for some years in succession, while the root-system develops until it attains sufficient vigour to produce a permanent stem. In the first year seedlings do not tolerate injury to the taproot, but in subsequent years it is possible to transplant them with a fair chance of success after pruning the root and stem. In nurseries seedlings are often killed through injury to the taproot by insects ; the grub of the rhinoceros beetle (*Oryctes rhinoceros*) is one of the worst offenders.

Young teak plants have a wonderful power of recovery from damage by fire, and in burnt forests their stems may be killed back for many years in succession, while in the meantime they gradually produce a much thickened root-stock from which a permanent shoot is finally produced when conditions are favourable to its survival. It has been observed in Burma that seedlings lacking in vigour when thus killed back by fire subsequently produce much more vigorous shoots. Young teak plants are not readily browsed by cattle and other animals.

Teak seedlings are intolerant of shade, and thrive best entirely in the open ; only in dry localities do they benefit in their earlier stages by side protection from the direct rays of the sun. They are very sensitive to any suppression by weeds, and it is a well-known fact that wherever weed-growth is to be feared the survival of teak seedlings cannot be ensured without regular weeding. This fact requires no demonstration to those who have had any experience of the cultivation of teak, but Fig. 273 may serve to demonstrate it to those who have not had such experience. This figure shows two parallel lines of teak sowings in the second year ; line A, on the left, has been regularly weeded, with the result that the plants are healthy and vigorous, while line B, on the right, has been left unweeded, with the result that every seedling has been killed by weeds, although these are by no means heavy. These sowings were carried out at Dehra Dun in 1913.

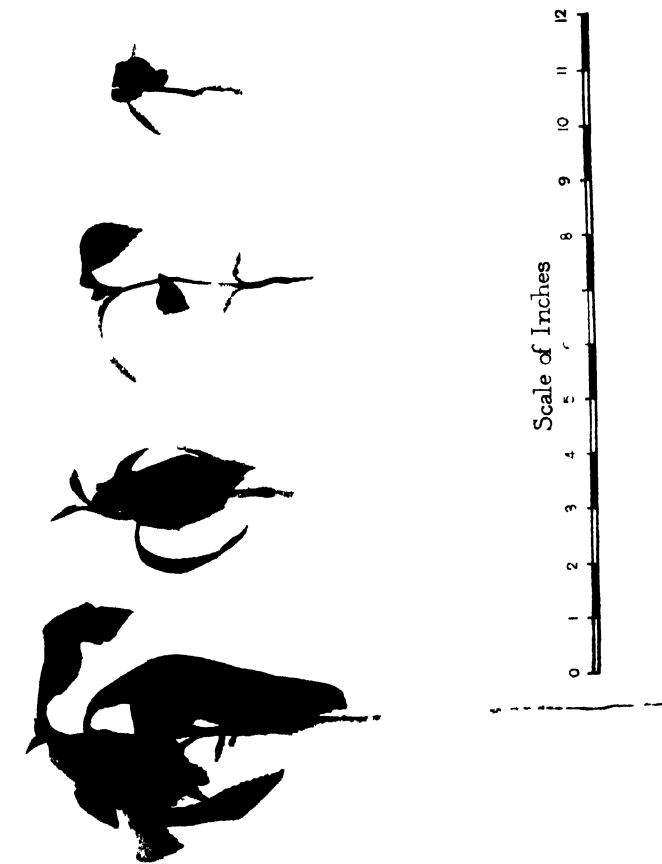


FIG 271 *Tectona grandis* seedlings in different stages up to 2 months old.



FIG 272 *Tectona grandis* vigorous seedling in first season
Staff shows feet



FIG. 273. *Tectona grandis*, line sowings in second year, Dehra Dun showing effect of weeding.
Line on left (A) regularly weeded, line on right (B) sown at same time and left unweeded.

The action of weeds in killing teak seedlings is probably not a matter entirely of suppression. Seedlings are very apt to rot in damp situations during the rainy season, and in moist weed-growth the mortality from this cause is high. Drip from overhead trees is also the cause of high mortality among seedlings, and possibly this may also be connected with rotting owing to excessive damp.

SILVICULTURAL CHARACTERS. The soil requirements of the teak have already been described ; briefly stated, the tree is capable of thriving on a variety of soils and geological formations, but requires good subsoil drainage. Teak is a pronounced light-demander ; it will not tolerate suppression at any period of its life, and requires complete overhead light as well as a fair amount of side room for its proper development. Saplings are often found growing under the light shade of bamboos, and even to some extent under other trees, but the growth of such plants will generally be found to be slower than that of plants with complete freedom overhead. Saplings growing under bamboos and endeavouring to make their way through them will often be found to have their leading shoot damaged or killed, the bamboo acting as a ' whip ' ; the leading shoot of the teak is very intolerant of any irritation of the kind.

The teak produces a large deep root-system. At first a long thick taproot is formed ; this may persist or may disappear, but in either case strong lateral roots are produced. Teak planted in the Andamans in exposed places suffers from the effects of wind, which causes a branchy growth ; it requires to be planted in sheltered places, belts of forest being left as screens.

Teak is sensitive to frost, seedlings and coppice-shoots being particularly liable to injury ; it resists frost better than some of its associates, however, and has good power of recovery. In its natural habitat severe frosts seldom occur, but the abnormal frost of 1905 did much damage in parts of the Peninsula, poles being killed at the top or down to ground-level ; experiments carried out for five years subsequently showed that trees badly damaged by frost were capable, when coppiced, of producing vigorous stool-shoots. Teak is also sensitive to drought. In the abnormal droughts which have occurred from time to time in the Peninsula it has usually suffered more severely than any other species, trees as well as coppice-shoots being killed or hopelessly injured in large quantities.

Teak has greater power of resisting the effects of fire than the majority of its associates. It is true that on steep hill-sides and on ground covered with a dense growth of inflammable grass the damage done by fire to teak trees in all stages is considerable, and it is not improbable that in such places much of the hollowness observable in the lower parts of the boles is attributable to the effects of past fires. Looked at from a comparative standpoint, however, it is equally certain that in burnt areas the survival of the teak as a species is encouraged at the expense of its less fire-resistant competitors. The question of the effect of fire and fire-protection on the natural reproduction of teak is one quite apart from the effect of fire damage on the growing stock, and is discussed below under ' natural reproduction '. Under certain conditions fire may have a beneficial influence in effecting a natural cutting-back process in the case of injured or weakly saplings. Thus Mr. C. B. Smales¹ has recorded

¹ Notes on a Tour in Forests on the West Slopes of the Pegu Yoma, 1917.

some interesting observations on the quality of teak saplings in fire-protected and unprotected forests of a dry type in the Zigôn and Thayetmyo forest divisions of Burma. In the protected forests most of the saplings were forked and many were crooked, while many suffered from injury by wind, temporary suppression, and other causes, and had wounds which persisted. In the unprotected forests such weakly shoots were removed by fire, and the shoots resulting from the regrowth were nearly always remarkably clean and vigorous, defying fire and all competitors.

An unexpected result was obtained in an experiment commenced in the Bhamo district, Upper Burma, in 1900. Two plots of forest were selected near each other; the growth on either was similar, consisting of numerous young teak trees with bamboos (*Cephalostachyum pergracile* in flower and *Dendrocalamus membranaceus*) and thekké grass (*Imperata arundinacea*). One plot, 6 acres in extent, was then fire-protected continuously after 1900, while the other, 5 acres in extent, was allowed to burn each year. By 1908 the condition of the plots was totally different. In the fire-protected plot there was a dense mass of bamboos, while in the burnt plot there were scarcely any. Measurements of about 100 teak stems in each plot showed a girth increment 43 per cent. greater in the burnt than in the fire-protected plot, the explanation being that in the former the crop was kept more open than in the latter, in which a dense growth of bamboos and inferior species was encouraged, to the detriment of the development of the teak trees. This experiment can hardly be regarded as conclusive in itself, but similar experiments in other localities might throw more light on what may prove to be a question of some importance.

Teak is not so readily browsed as most of its companions, and resists the effects of grazing better than they do. Mr. J. W. Best¹ alludes to a stunted and shrubby growth in heavily grazed areas in the Bhandara district, Central Provinces, but this is attributed to the hardening of the soil by continued trampling rather than to actual browsing. Heavy grazing may be decidedly harmful in young coppice areas, as the coppice-shoots are soft and easily broken or trampled down by cattle.

In resisting the effects of mechanical injury of any kind the teak shows remarkable vitality. In village forest lands in the Indian Peninsula the last remnants of a former forest are often represented by a scrubby growth of teak, the last surviving species in the process of lopping, cutting, burning, and grazing. On annually cleared fire-lines, again, teak coppice-shoots persist longer than those of most other species. In some localities teak owes its survival in part to the fact that as a 'royal tree' it has received special protection for a long period of years, but apart from this it owes its prevalence in many places where it constitutes the bulk of the growing stock to its great power of resistance to the effects of hacking, burning, and grazing.

Teak suffers from various forms of injury by animals. In the Peninsula rats multiply in certain years and do considerable damage in plantations by gnawing the roots. Pigs also do much damage in some parts of the Peninsula by rooting up seedlings, particularly in plantations, where the newly-dug earth attracts the animals. In Burma much damage is done in some localities by

¹ Ind. Forester, xxxv (1909), p. 613.

saing (*Bos sondaicus*), which strip off the bark from teak poles and often kill them outright. This form of damage is also perpetrated by bison and sometimes by deer. Of all wild animals, however, the elephant is the worst offender, his depredations being noticeable to some extent in Malabar and on a larger scale in Burma. The damage consists of breaking down or uprooting poles, especially in plantations, which may be utterly ruined, and of stripping the bark off trees. The latter form of damage is done by digging the tusks under the bark, tearing it open, and then pulling it off in long strips. The bark is often stripped off completely round the lower parts of the trees, many of which are killed, while, if they survive, the wounds caused by the barking may admit fire and rot. Mr. G. R. Jeffery¹ estimated that in the Wapyudaung working circle, Ruby Mines district, about 90 per cent. of the unsound trees in the moister types of forest owed their unsoundness directly or indirectly to damage by wild elephants, and concluded that it would be impossible to grow sound teak in forest infested by these animals.

Teak is subject to various insect attacks, perhaps the most serious of which is that of the larva of *Duomitus ceramicus*, Wlk., a moth, which bores into standing trees in Burma and causes the large holes erroneously termed 'bee-holes'. Another lepidopterous borer, *Cossus cadambae*, Moore, does much damage in Travancore. It tunnels down the interior of young stems one to two years old, and the only remedy is to cut back the stems; it also gains admission through the wounds caused by lopping branches of trees for manure. Of defoliators, the commonest are the caterpillars of *Hybloea pueri*, Cram., and *Pyrausta machaeralis*, Wlk. The former consumes the whole leaf except the midrib and the main lateral veins, while the latter skeletonizes the leaves, eating the parenchyma and leaving all the veins. Another defoliator is the caterpillar of *Paliga damastesalis*, Moore, the 'teak-leaf roller', which, though more local, does a considerable amount of defoliation in some localities, particularly on dry hill-sides.

The fungous pests of the teak have not been studied in any detail. In Upper Burma the existence has been recorded of a thread-like blight on teak leaves and of a fungus in the plantations of Katha which arrests the growth of the leading shoot, causing a nest-like formation; cutting back has been found effective in the case of the latter fungus. In the Gwethe reserve of Toungoo in 1911-12 a group of teak trees 5 to 7 ft. in girth was found to be attacked by a fungus, which had killed some of the trees; specimens were examined at Pusa by the Imperial Mycologist, who reported great destruction to the woody elements by a fungus which appeared to be strongly parasitic, but without the sporophores the fungus could not be identified. A mildew, *Uncinula Tectonae*, Salmon, which attacks the leaves of the teak and of *Cordia Macleodii*, appears to be fairly widespread in the Central Provinces. Mr. A. L. Chatterji² notes that it attacks only the upper surface of the leaves, giving them a characteristic bluish appearance. The fungus does not appear to do any material damage.

In some localities teak suffers from the attacks of *Loranthus*. This parasite was at one time troublesome in the Nilambur plantations, but branches

¹ Working Plan for the Wapyudaung Working Circle, Ruby Mines Forest Division, 1911.

² Ind. Forester, xxxviii (1912), p. 28.

attacked by it have been systematically lopped, and it has thus been kept in check.

Teak coppices and pollards vigorously, and sometimes retains the power of coppicing to a considerable size. Mr. Foulkes¹ mentions a tree in North Malabar with a breast-height girth of 97 in., which when felled produced 22 coppice-shoots, and stems with *diameters* of 2 ft. 10 in. to 6 ft. 4 in. which produced 11 to 13 shoots per stool. The early growth of coppice and pollard shoots is rapid. Of twelve different species coppiced and pollarded experimentally in 1909 in North Chanda, Central Provinces, teak showed the most rapid growth both of coppice and of pollard shoots. Mr. J. C. Legge² records measurements of coppice-shoots from stems five years old cut back in plantations in Travancore on February 14–17. These were measured on May 11, when less than three months old, and were found to vary from 3½ to 7½ ft. in height, the number of shoots per stool varying from 7 to 23: an unusual fall of 10 in. of rain, however, occurred at the time of cutting back. An average height of 7 to 10 ft. for coppice one year old is not unusual.

An experiment carried out in 1906 in the Jubbulpore district, the object of which was to ascertain the most favourable season in which to carry out coppice fellings, has been described by Mr. R. S. Hole.³ Trees 2 to 4 ft. in basal girth, selected for equal vigour and similar conditions of environment, were coppiced in different months from March to September. The stools were cut flush with the ground. The best results were obtained in March and September, and the worst results, with reference to three different factors, were obtained as follows:

Factor.	Months giving worst results.
Total and partial failure to coppice	April, May, June, July.
Number of dominant stems	June, July, August.
Height growth	July, August.

Thus the worst period for coppicing was found to be from the time vegetative activity commences—it was abnormally early that year—up to and for a short time after the full development of the foliage. In the course of this experiment it was found that in the case of the larger stools, with 3–4 ft. girth, the number of vigorous shoots per stool was greater than in the case of the smaller stools, with 2–3 ft. girth. The following are the figures:

Girth of stool.	Average number of vigorous shoots per stool according to month of felling.						
	March.	April.	May.	June.	July.	Aug.	Sept.
2–3 ft.	1·7	2·0	1·8	1·6	1·9	1·6	2·4
3–4 ft.	4·0	3·8	2·5	2·1	2·0	2·2	2·7
Average of all sizes (2–4 ft.)	2·3	2·6	2·3	1·9	1·9	2·0	2·5

All the coppice-shoots originated in one of two ways—(1) from callus growth developed inside the bark and situated between the bark and the wood at the edge of the cut surface, or (2) from the side of the stool below the cut surface, the shoots appearing through the bark. The former, which may be

¹ Ind. Forester, xl (1914), pp. 262, 263.

² *Ibid.*, xxiii (1897), p. 205.

³ Note on the Best Season for Coppice Fellings of Teak, For. Pamph. No. 16, Bot. Ser. No. 1, 1910.

termed 'callus shoots', are of adventitious origin, while the latter, which may be termed 'side shoots', probably arise from dormant buds. Mr. Hole notes that high coppicing appears to prevent the formation of callus shoots owing to the rapid drying and shrinking of the wood at the cut surface, causing separation from the bark: also that, subject to further confirmation, present evidence seems to show that it is best to coppice teak low shortly before the commencement of vegetative activity, when as little of the dry season as possible remains, or if felling must be done in the season of rest, high felling may possibly be preferable, so that the base of the stump will still remain alive if the upper part dies.

It is stated¹ that observations in the Melghat, Berar, have indicated that in the case of old teak stumps whose vitality is poor it is better to leave stools 4 or 5 in. high than to trim them flush with the ground, as in the latter case the dormant buds appear to be cut away.

Experiments carried out in 1909 in North Chanda to some extent corroborate the Jubbulpore experiment as regards the season for coppicing teak. Stools coppiced in successive months from April to September showed the following percentage of success in producing shoots: April 100, May 100, June 92, July 91, August 40, September 71.

There is little doubt, from observations made in localities where felling or coppicing has been carried out for a long series of years, that teak stools retain their vitality for a considerable time, and also, particularly in the case of old hollow stumps cut flush with the ground, that the coppice shoots may develop independent roots of their own, and may have the external appearance of independent plants, until a search below the surface of the ground reveals the fact that they are connected by the periphery of the old stump. In some cases this connexion may possibly disappear in course of time.

The question whether or not teak produces root-suckers has been the subject of some inquiry. In his account of teak in the Wynaad, North Malabar, Mr. G. F. Foulkes states: ² 'Where free seedling reproduction is absent the tree reproduces itself from coppice-shoots and more chiefly from root-suckers. This is the case at the present time not only in the Wynaad but throughout the teak areas of the Madras Presidency.' The statement that teak reproduces from root-suckers, which is reiterated elsewhere in the same article, evolved some comment from Forest Officers in other localities, and an inquiry was accordingly instituted with the view of ascertaining to what extent the production of root-suckers is a general characteristic of the teak. A search was made for root-suckers in different provinces and localities, including North Malabar, and reports and specimens were sent to Dehra Dun. As a result of this inquiry Mr. E. Marsden³ contributed a paper summarizing the conclusions arrived at. An examination of the various specimens received, which included specimens from North Malabar, revealed certain characteristics common to all, namely:

(i) The "root-suckers" are close to each other or to the parent stem (usually not so far that their point of attachment to the "root" could not have been reached by a buttress or a lateral extension of the stem).

¹ Annual Forest Administration Report, Berar Circle, 1913-14.

² Ind. Forester, xl (1914), p. 192.

³ *Ibid.*, xlii (1916), p. 43.

- ' (ii) The " roots " are damaged or eroded on the upper side.
- ' (iii) The roots are near the surface.
- ' (iv) The parent stem is generally decayed.'

Now the vitality of teak stumps is remarkable ; trees which have been coppiced at times send up stool-shoots low down on the stool at the base of the buttresses which are the upward continuations of the main lateral roots. The centre of the original stool may die and in time decay or become burnt, but the stool-shoots remain alive and may form independent root-systems, though they may remain connected by the periphery of the original stump. If these coppice-shoots are in their turn felled, new shoots may be produced on the side away from the original stump · the subsidiary stumps from the second coppicing may in their turn die and decay or become burnt, the result being a group of shoots apparently arising from lateral roots, and in some cases connected together by the root-like living periphery of an old stump, the interior of which has disappeared. Such was evidently the origin of the various specimens of ' root-suckers ' received at Dehra Dun, none of which appear to have arisen otherwise than in close proximity to the parent stem

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' To ascertain whether these shoots were true suckers, or merely one of the many instances of ordinary shoots that spring up more or less in contact with the parent stool, the following experiments were carried out

' 1. I had the soil dug up round eight trees, which I then cut down below the level of the ground · In two out of the eight cases, just enough of the stem was left to keep the principal roots connected. In the rest the stem was quite cut out, separating these roots entirely from each other ; along with the stem a less or greater portion of the root was, of course, removed. The earth with chips of wood was then thrown back. All the trees were over 80 years old, three of them hollow and decaying.

' 2. I wounded the exposed portions of the principal roots of upwards of 100 trees. In some cases a chip of bark only was taken off with a sharp axe, in others a portion of wood was also removed ; some of the wounds were made with a blunt instrument, others with a stone, and so on. A considerable number of wounds were more or less covered over with fine earth, or ashes, or cow-dung.

' 3. Similar wounds were made in the underground portions of many principal roots, and lightly covered over with soil.

' 4. And lastly, I dug up carefully the extremities of some principal roots and covered most of them up lightly with soil, leaving some in their natural position, others slightly bent upwards, to favour the production of suckers, if any were likely to come up.

coppiced did not show a single shoot that had not sprung up in contact with the stools. Besides this, on many occasions when I have met with young teak plants that from their position to trees near them looked like suckers, I have had them carefully dug round and have invariably found their roots entirely distinct from those of the suspected parent trees.'

So far as direct evidence goes at present, then, it may be said that teak does not possess the tendency to throw up true root-suckers at a distance from the parent stem, and that the so-called 'suckers' which spring from low down on the stump, at its junction with the main lateral roots, although they may in certain cases bear a close resemblance to true root-suckers, should more correctly be regarded as stool-shoots. True root-suckers, such as those of *Dalbergia Sissoo*, *Butea frondosa*, *Oroxylum indicum*, and many other trees, if they are produced by the teak, must be of rare or local occurrence.

NATURAL REPRODUCTION. The natural reproduction of teak has been the subject of numerous experiments and observations which enable us to arrive at certain conclusions regarding the effects of various factors, favourable or otherwise, which bear on it. Our knowledge of the subject, however, is by no means complete, and much detailed research still remains to be done. The factors influencing natural reproduction may be considered under three heads: (1) spread of seed, (2) factors influencing germination, and (3) factors influencing the survival and development of the seedling.

(1) *Spread of seed.* Under natural conditions the fruits begin to fall in the cold season, about December or January, and continue falling during the ensuing hot season. On more or less level ground they fall and remain under and around the trees until, if conditions are favourable, germination takes place. On hill-sides where there is an insufficient soil-covering of grass or other plants to hold them up, many fruits are washed down the slopes early in the rainy season. The chief transporting agency of teak seed is water, and this accounts in part for the fact that teak often springs up gregariously on alluvial flats, whither the fruits are conveyed in the season of floods and deposited in quantity.

(2) *Factors influencing germination.* Given a sufficient degree of moisture, the chief factor influencing germination is temperature; soil-aeration is a probable factor, while certain other factors are brought into play in connexion with the burying of the seed.

(i) *Temperature.* A temperature sufficiently high to induce ready germination may be produced either by the heat of the sun or by fire. In cool shady places teak seed germinates with difficulty or not at all, and may lie dormant for years, eventually germinating in quantity as soon as the direct rays of the sun are admitted to the ground by the opening of the canopy and the clearing of undergrowth. This is amply demonstrated by the regenerative operations in the Mohayin forest described on p. 752 and by some of the examples quoted below. Mention may also be made of an experiment carried out by Mr. Hole at Dehra Dun.¹ Seed was sown on July 2, 1913, in two adjacent plots, one open to the sun and rain, the other completely shaded from the sun but receiving all the rain which fell: the percentage of germination was 17 in the former and 1 in the latter. After two years the open plot

¹ Ind. Forester, xlii (1916), p. 51.

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' Of the eight trees exploited underground, five threw up shoots the following rains, among these the two in which a portion of the stem was left. These latter, it must be noticed, produced the greatest number of shoots. In the three other successful instances the shoots sprang up from, or close to, the section of the roots ; the three cases of failure were those in which the largest portions of the principal roots were cut away with the stem. Making allowance for differences of soil, the strongest shoots were produced by those which had lost the least portion of their principal roots. Experiments 2, 3, and 4 were complete failures ; moreover, an inspection of over 5,000 stools

¹ Forest Conference, Simla, 1876.

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was full of vigorous seedlings, but of the few seedlings which germinated in the shaded plot none survived. The shade over the latter was removed on June 28, 1915, and the admission of the sun's heat was at once followed by the germination of a number of seeds which had lain dormant for two years. Numerous instances have been recorded in the forest of teak seedlings appearing in quantity where the canopy has been opened; some of these are quoted below. Germination is greatly stimulated if the seed lies in the open exposed to a thorough baking by the sun during the hot season, and to the alternate soaking and heating which it experiences during the early showers preceding the monsoon proper. Germination then takes place chiefly at the beginning of the monsoon, though in some cases it may continue throughout the greater part of the rainy season. A case of failure of seed to germinate when lying in an area shaded laterally is described below (p. 722).

The beneficial effect of fire in stimulating the germination of teak seed is now thoroughly realized in Burma. Experiments which I carried out in that province in 1903 and 1904 showed that slight scorching, such as would occur in a light leaf fire, stimulates germination, but that severe scorching, amounting to charring of the fruits, destroys the vitality of the seed; the latter condition is produced by the firing of a thick layer of leaves or of a somewhat heavy growth of grass. Under natural conditions the fruits fall partly before and partly after the season of fires, and in burnt forests it is probable that a portion of the seed-crop is destroyed by fire while a portion has its germination stimulated by fire, the net result depending a good deal on the nature of the soil-covering. In the case of seed lying dormant in the ground, fire undoubtedly has a stimulating effect on germination, as various experiments in Burma in cutting and burning the undergrowth have shown. The measures now adopted in Burma for securing natural reproduction are described in detail on p. 755; it will be seen that thorough burning is regarded as essential to success. The beneficial action of fire is probably connected not only with the heat produced by it, but also with its action in clearing and aerating the ground. An experiment in Coorg¹ may here be referred to, in which the undergrowth below twelve trees was burnt in the hot weather of 1908, with the result that a large number of natural seedlings sprang up, of which only 184 survived the drip from the mother trees during the subsequent monsoon.

(ii) *Soil-aeration.* In the experiment referred to above, Mr. Hole demonstrated that an admixture of dead teak leaves in fairly heavy loam was beneficial to germination when the soil was kept well aerated and fully exposed to light and air, but was injurious when kept constantly wet. In my experiment at Tharrawaddy, described below, the beneficial effect of hoeing the soil is clearly shown. Further experiments, however, are necessary to determine the precise effects of soil-aeration under different conditions.

(iii) *Burying of the seed.* Experiments at Dehra Dun, which were repeated several times, showed that seed lying on the surface of the ground exposed to the sun almost invariably fails to germinate owing to the fact that the radicle dries up or is eaten by insects or birds before it penetrates the soil; the drying up of the radicle is particularly liable to occur on hard ground.

¹ For. Admin. Report, Coorg, 1907-8.

Actually on bare ground teak seed becomes buried naturally in a remarkably short space of time. Rain is the chief agent in burying the fruits, but white ants frequently devour the outer felty covering, leaving the inner hard nut intact, and these insects no doubt assist in burying them. In experimental plots at Dehra Dun a quantity of fruits scattered on bare ground in February had almost all become buried before the end of July : on grass-covered ground they remained for the most part on the surface uncovered, but here germination was moderately successful owing to the protection from the sun which the grass afforded during the process. The beneficial effects of loose soil are due in part to the fact that it facilitates the burying of the fruits. A covering of half an inch or less is quite sufficient, seed buried deeper germinating more tardily.

(iv) *Combinations of factors.* An experiment which I carried out at Tharrawaddy, Burma, in 1904, throws some light on certain combinations of factors influencing the germination of teak. Eight adjacent plots were marked out in the open, exposed to the full effect of the sun's heat and light. In each plot 100 teak seeds, not treated in any way, were sown. In six of the plots, which may be termed A, sowing was carried out on April 13, that is, before the first showers, and in the remaining two plots, which may be termed B, sowing was carried out on June 23, that is, after the monsoon had well set in. The method of preparation of the plots and the results of the germination were as follows :

Tectona grandis : results of germination experiments, Tharrawaddy.

Method of preparation of soil and sowing of seed.			Percentage of seeds which germinated up to date.		
			June 18.	June 24.	July 17.
<i>A. Sowing carried out on April 13.</i>					
Area burnt ; about 3 in. layer of leaves	Soil not prepared	Seed sown broadcast and not covered (1)	26	27	28
		Seed sown broadcast and not covered (2)	32	43	47
	Soil loosened with hoe	Seed sown broadcast and lightly covered (3)	67	75	81
		Seed sown broadcast and not covered (4)	Nil.	8	11
	Soil not prepared	Seed sown broadcast and not covered (5)	19	21	25
		Seed sown broadcast and lightly covered (6)	42	42	44
Area not burnt ; sparingly covered with dry short grass at time of sowing	Soil loosened with hoe	Seed sown broadcast and not covered (7)	No germination took place throughout the rains: even had it done so the young plants would have had a harder struggle against weeds than those in plots A.		
		Seed placed in shallow holes and lightly covered (8)			
<i>B. Sowing carried out on June 23.</i>					

Although a single experiment of this kind cannot be regarded as conclusive, yet it confirms results obtained in other experiments, and indicates : (1) that germination is greatly stimulated if the seed lies exposed to the sun from before the commencement of the early showers preceding the monsoon.

and that without this early exposure it may fail altogether during the first year, even in the open ; (2) that the best results are obtained by burning the soil-covering, hoeing up the soil, and lightly covering the seed ; (3) that the worst results are obtained in the case of seed lying uncovered on ground neither burnt nor loosened.

In this experiment it was noticeable that the seedlings made the best start and the weed-growth was retarded most on ground burnt and hoed, while on ground not burnt but hoed up conditions were nearly as good. Weed-growth was most plentiful on the plots which were neither burnt nor hoed up ; on these a tall growth of grass and weeds sprang up early, and by July had begun to kill out the seedlings.

(3) *Factors influencing the survival and development of seedlings.* So far as is known the chief factors influencing the establishment of natural reproduction are (i) light, (ii) soil-aeration, (iii) soil-moisture, (iv) weed-growth, (v) grazing, and (vi) fire.

(i) *Light* is one of the most important factors in the establishment of natural reproduction, the teak being a strong light-demander from its earliest youth. Although saplings may persist for a time under the light shade of bamboos and other overhead cover, their development is slow and they become readily suppressed. Experiments carried out within recent years in Pyinmana and Prome have shown that a sudden influx of light to badly suppressed teak saplings, far from causing their recovery, may cause their death. The admission of light by the opening of the overhead cover is the main object of so-called improvement fellings for the benefit of the young crop in natural forest. In Burma, where bamboos play such a prominent part in the composition of the forests, excellent teak reproduction is often seen in areas where elephants have been herded for some time in connexion with timber extraction ; these animals perform a useful service in breaking down the bamboos and admitting light and warmth to the ground, with the result that teak seedlings sometimes spring up and establish themselves in a manner suggesting a well-stocked plantation. At the same time elephants, if kept longer than is necessary in such areas, may undo the good they have done owing to their propensity for damaging young teak poles. Intensive bamboo exploitation has a similar effect in stimulating teak reproduction. Again, along the sides of dragging-paths, on fire-lines and in other openings through the forest, natural reproduction tends to spring up freely (see Fig. 274). Along the sides of dragging-paths and where exploitation has been in progress the breaking up of the soil no doubt also acts favourably, apart from the admission of light. Mr. R. Bourne has noted an interesting case of the adverse effect of side shade in one of the Nilambur plantations. Part of the Aravillicava plantation was clear-felled in 1917, and natural reproduction sprang up in quantity in July ; in places the seedlings were so dense that it was hardly possible to step without treading on them. This clear-felled area had already been planted up the previous month and the new plantation was weeded without damaging the natural seedlings. In this clearing were two areas on which shade was cast for a considerable period in the morning by the adjoining plantations, which were 90 to 110 ft. high. Here not only did no natural seedlings spring up within the area shaded after 8 to 9 a.m., owing to the temperature necessary for germina-

tion being insufficient, but the planted seedlings showed markedly poorer growth in that area than they did in the open. On the edge of the clearing the drip from the overhanging trees in the adjoining plantations certainly affected the young plants ; but in the shaded areas the breadth affected and devoid of all natural reproduction was in places as much as 130 ft., and it is therefore beyond question that the absence of natural reproduction and the inferior growth of the planted seedlings were the direct result of the lateral shade.

(ii) *Soil-aeration* is a term which may for the present be applied, for want of a better one, to certain conditions which have a marked effect on the establishment or failure of natural reproduction. Under this head may be included the tendency of teak seedlings to rot in excessively moist or water-logged situations, and where damp weed-growth exists ; the mortality from this cause during the rainy season may be very high. The wholesale death of seedlings during the rainy season owing to the drip from overhead trees may possibly be attributable, in part at least, to the same cause. It has sometimes been attributed to some toxic effect in rain water falling from teak leaves, but this is mere conjecture. Whatever the precise nature of the adverse influence may be, it is a well-known fact that seedlings are killed off in large quantities by the drip from overhanging trees, and that anything short of complete clearance of the overhead canopy is liable to result in high mortality among teak seedlings in forest at all approaching a moist type. The aeration of the soil by loosening has a marked effect on the development of young plants, and in dry localities it is a useful means of stimulating a strong and healthy growth which enables seedlings to survive drought. In the experiment alluded to above, Mr. Hole found that an admixture of dead teak leaves in fairly heavy loam was beneficial to the growth of teak seedlings when the soil was kept well aerated and fully exposed to light and air, but was injurious when kept constantly wet. The vigorous growth of teak seedlings on the sites of old charcoal kilns and on patches of burnt débris is probably attributable to the aeration of the soil in such places. Soil-aeration plays an important part in the establishment of seedlings under the system of mulching described in the next paragraph.

(iii) *Soil-moisture*. Deficiency of soil-moisture is one of the greatest obstacles to the establishment of natural reproduction in many parts of the Indian Peninsula, particularly in forests of a dry type. Seedlings often appear in quantity at the beginning of the monsoon, but have to contend against weeds during the rainy season, with the result that those which survive the struggle are weakly plants, which succumb to drought during the ensuing dry season. Any measures which will tend to promote vigorous growth during the early life of the seedling are likely to aid it in surviving the effects of drought, and the measures first tried with success by Mr. W. E. Copleston in the Haliyal teak pole forests in the drier parts of the Kanara district and now adopted in other parts of Bombay, have proved to be an effective method of securing the survival of natural seedlings in localities where under ordinary circumstances they are liable to perish from drought. The survival of the seedlings is secured by a system of surface mulching. The mulch consists of a small armful of green twigs with leaves, grass, or even dead material, the refuse of the fellings, spread in a ring round the plant ; on this

are thrown two or three spadefuls of earth. According to Mr. Copleston,¹ the soil round the plants is not loosened, and the two main objects of the mulch are (1) to keep the soil round the plants free from weeds, for which purpose a six-inch layer of grass and leaves, with a very little soil to keep them in their place, is sufficient to keep the ground clean for a whole year; (2) to secure the loosening and aeration of the soil by worms and insects, for after the mulch has been down a month in the monsoon a mass of worm-casts and much tunnelling by insects may be found under it. The class of forest to which this system of mulching is applied is thinly stocked pole forest of teak on dry, hard, stony ground; the rainfall is only about 30 in. The results are remarkably good, for in coupes where formerly no seedlings survived it is possible to establish from 200 to 300 per acre at a cost of between Rs. 3 and Rs. 4 per acre. This method of tending natural seedlings has recently been tried in the Melghat, Berar; in open places the results were good, but where there was any drip from overhanging trees the seedlings failed to survive.

(iv) *Weed-growth.* The intolerance of teak seedlings to suppression by weeds has already been alluded to under 'the seedling'; weed-growth is one of the most serious obstacles to the establishment of natural reproduction, which in areas where weeds are prevalent can be secured in quantity only by means of systematic weedings commenced in the first rainy season and continued regularly until the plants are free from the risk of suppression.

(v) *Grazing.* If not heavy, grazing appears to favour the reproduction of teak rather than otherwise, by keeping down heavy grass and undergrowth. Experiments were carried out in 1914 in the Wardha district, Central Provinces, in which cattle were admitted into coppice coupes which had been closed to grazing for three years after felling. This resulted in little or no injury to the teak coppice or seedlings, but one year's grazing stimulated such a rank growth of *Cassia Tora* and *Indigofera glandulosa* as to threaten further teak reproduction.

(vi) *Fire.* In the drier types of teak forest, such as those met with throughout a considerable part of the Indian Peninsula, fire is admitted to have an adverse influence on the establishment of teak reproduction, which is greatly assisted by fire-protection. In many of the moister types of forest, on the other hand, it has now been proved beyond doubt that indiscriminate fire-protection exercises an adverse influence on teak reproduction by encouraging the growth of inferior species, bamboos, and dense undergrowth at the expense of the more fire-resisting and light-demanding teak. We are not concerned here with the question of damage done by fire to the standing crop, or to the effect it is sometimes held to have in impoverishing the soil; nor are we concerned with the effect of fire-protection on the drier types of forest, but only with its effect on the moister types of teak-bearing forest constituting most of the best teak areas in Burma and along the Western Ghats. In the latter region the adverse effects of continued fire-protection in the moister types of teak forest have been noticed for some years past, but the matter has received more attention in Burma than elsewhere owing to the large extent and the great importance of the moister types of forest, where the teak reaches its best development.

¹ Ind. Forester, xlv (1919), p. 82.



FIG 274. Natural reproduction of teak along old dragging-path,
Pyinmana, Upper Burma.



FIG. 275 Forest of *Bambusa polymorpha*, never fire-protected, with natural reproduction of teak on the ground, Tharrawaddy, Burma.

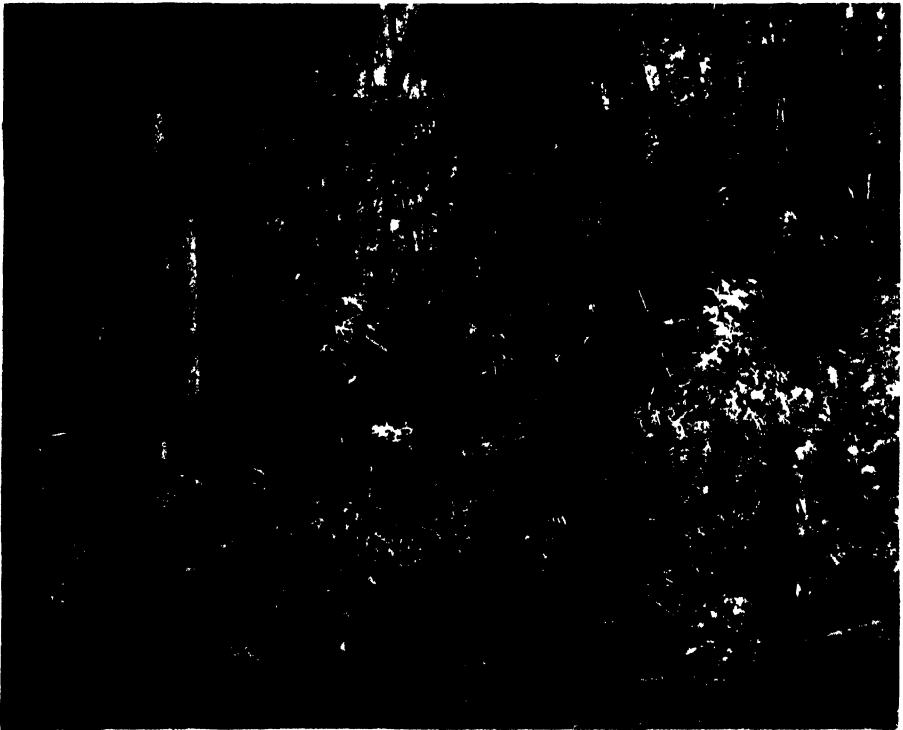


FIG. 276. Dense young growth of *Cephalostachyum pergracile* under *Bambusa polymorpha* in forest which has been fire-protected for 14 years, Tharrawaddy, Burma.

In Burma the precise effects of annual burning and of continuous fire-protection on the condition of the forest and the undergrowth are easy to observe. Where, as is usual, bamboos form as it were the matrix of the forest, fire-protection has the effect of greatly increasing the luxuriance of the bamboo growth, so much so that the establishment of teak seedlings, even if germination were possible, is out of the question. Figs. 275 and 276 respectively show typical forest of *Bambusa polymorpha* and *Cephalostachyum pergracile*, the former never fire-protected and containing teak reproduction, and the latter successfully fire-protected for fourteen years, during which time so dense a growth of bamboo has taken possession of the ground that teak reproduction is quite unable to establish itself. Longer periods of fire-protection show even greater changes, and in many cases the forest becomes converted from a deciduous to an evergreen type by the encouragement of sensitive evergreen shade-bearers. In annually burnt teak forests of the type under consideration the seedlings, it is true, may be burnt back year after year, meanwhile developing thick root-stocks, but their wonderful power of recovery enables them to survive, and even to gather strength with each successive burning back, until eventually the time comes when the seedlings are able to survive the burning and to establish themselves as strong healthy plants.

The desirability of extending fire-protection throughout all classes of teak-producing forest in Burma was first called in question by the late Mr. H. Slade in 1896.¹ The interest in the matter which was thus awakened resulted in a mass of evidence being collected, the great bulk of which affords ample proof that in the moist types of teak-bearing forest indiscriminate fire-protection is detrimental to, and may entirely prevent, the natural reproduction of teak, and that if it is continued it is likely to result in the total disappearance of teak throughout large areas of the most important class of teak-bearing forest in Burma. The recognition of this fact has resulted in the abandonment of fire-protection over considerable areas where its results are known to be detrimental to the reproduction of teak. It may be of interest here to examine some of the evidence which has led to this step being taken.

The first actual enumerations made with the view of comparing the stock of young teak trees in fire-protected and burnt forest respectively appear to have been those which I carried out in 1905 in two adjoining plots, one inside and the other outside the external fire-line of the Kadinbilin reserve in Tharrawaddy.² The former plot, 37 acres in area, had been successfully protected from fire for thirty-two years, and the latter had never been fire-protected. The plots were typical of the usual moist mixed forest of the Pegu Yoma, the bamboos being *Bambusa polymorpha* and *Cephalostachyum pergracile*. Prior to the introduction of fire-protection, both plots must have been precisely the same in appearance and character; at the time of the enumeration, however, prolonged fire-protection had greatly increased the density of the bamboos in the protected plot. There was a sufficiency of teak seed-bearers in both plots to secure ample reproduction under favourable conditions. In both plots bamboo extraction had been carried on for many years, and in the fire-protected plot improvement fellings had been carried out twice, and dibblings of teak seed had been made. Everything therefore favoured a plentiful crop of young

¹ Ind. Forester, xxii (1896), p. 172.

² *Ibid.*, xxxi (1905), p. 138.

teak in the protected plot, had conditions for its establishment been favourable. The enumerations revealed the following number of teak poles, saplings, and seedlings in each plot :

Tectona grandis : enumeration of natural young teak in fire-protected and unprotected plots, Tharrawaddy.

		Number calculated for 50 acres in each case.	
	Class.	Fire-protected plot.	Unprotected plot.
I. Poles 1 ft. to 2 ft. in girth	{ (a) Sound	174	135
	{ (b) Unsound and dead	109	29
II. Poles and saplings under 1 ft. in girth	{ (a) Sound	24	141
	{ (b) Unsound and dead	121	37
III. Seedlings		62	616

These figures reveal the fact that although the larger poles, which had established themselves prior to the days of fire-protection, were more numerous in the protected than in the unprotected plot, the seedlings—many being young plants which had been burnt back for some years and were only establishing themselves by degrees—were ten times as numerous in the unprotected as in the protected plot. A striking fact, which was wholly unexpected, was the large proportion of unsound and dead saplings and poles in the protected as compared with the unprotected plot. This was due to suppression by the bamboos ; in the unprotected plot weakly stems had to a large extent been killed back by fire and replaced by strong regrowth. In the protected plot the proportion of poles killed outright by suppression amounted to about 75 per cent. of the total number of suppressed and dead stems, and the remainder were so badly suppressed that there was no hope of their ever recovering. In the unprotected plot the sound poles were vigorous, bore no sign of fire damage, and had little to fear from future suppression, the bamboo clumps having been kept well apart by the annual burning ; the unsound and dead poles appeared to have suffered not from fire but from suppression in places where the bamboo growth was particularly luxuriant.

These enumerations give some idea of the holocaust of young teak plants which takes place in typical moist mixed teak forest in Burma as a result of prolonged fire-protection. Unwilling to accept the figures as conclusive, I appealed at the time for further evidence as to the effects of fire-protection in different localities, and such evidence has been forthcoming. In 1907 Mr. F. Beadon Bryant recorded the results of enumerations made in 1906 in various working plan sample plots, aggregating 275 acres, in the Tharrawaddy forests. These plots had previously been enumerated when the working plans were prepared twenty-one years before ; some of them had meanwhile been fire-protected for many years, others had been protected for a few years, and one had not been protected at all. Mr. Beadon Bryant's results confirmed those yielded by my enumerations, namely that prolonged fire-protection results in a marked decrease in the number of young teak trees in forests of the moist mixed type.

Similar re-enumerations have since been carried out in various parts of Burma, and the results have been recorded mainly in forest administration

reports. The figures so recorded do not always appear to be based on sufficiently comprehensive *data*, but there is enough reliable evidence to confirm in no uncertain manner the conclusions previously arrived at, to the effect that prolonged fire-protection in the moist types of teak forest is detrimental to the establishment of teak reproduction. As an indication of the adverse effects of fire-protection in certain of the forests of the Ruby Mines district, the following extract, which describes the condition of things after seven or eight years of successful fire-protection, may be quoted from the working plan of the Maingtha, Kunchaung, and Nanme reserves : ¹

' The effect of fire-protection here is that the undergrowth, naturally very dense and consisting largely of evergreen species, is rendered still denser : in *wabo* ² areas it is almost impenetrable, while in *tinwa* ³ areas on high ground, where light enters more freely, a heavy undergrowth of dwarf *tinwa* springs up. The result is that (1) teak seeds lying on a cold bed of decaying vegetable matter do not receive sufficient exposure to light and heat necessary to germination, seedlings are practically non-existent, and no new root-stocks are formed whence shoots may annually endeavour to establish themselves, (2) shoots on old root-stocks are more liable to suppression than they are in non-fire-protected forests. In drawing these conclusions it has been observed that trees grown direct from seedlings are practically never found in either fire-protected or non-fire-protected areas : reproduction consists entirely of shoots on old stocks, some very old, some only a few years old. These shoots are less plentiful in fire-protected than in non-fire-protected areas, but in neither are they common except where breaks in the undergrowth and low overhead cover have been formed, usually by removal of bamboos or groups of teak in semi-evergreen forest. But the most convincing part of the experiment ⁴ has taken place in the forest in the neighbourhood of Dogyaung, Asugyi, and Kwehaungdon villages, where bamboos have been heavily cut for a great number of years. In this locality, on the one hand, splendid groves of sound small teak trees of a girth of one or two feet may be seen which sprang up as the result of bamboo-cutting in the days when fire-protection had never been thought of ; they are not merely chance groups, as they occur freely over several compartments. On the other hand, although bamboos have been cut just as regularly and probably more heavily during the last eight years since fire-protection was instituted, there are now only a few fair patches of reproduction, and no considerable number of seedlings or stool shoots to be found on corresponding areas ; and they ought to appear in still greater numbers if fire-protection is to be justified.'

These remarks are the more interesting in that the writer, Mr. Walsh, admits having commenced his observations with preconceived ideas ' that correct conservancy of every type of forest included the prevention of fire '.

Although it is now generally agreed that continuous fire-protection is detrimental to, and may entirely prevent, the natural reproduction of teak in the moist types of teak-bearing forest in Burma, our knowledge of the subject is by no means complete. The value of fire-protection in the dry types of teak forest in the Indian Peninsula is fully admitted, and there is in all probability a stage between the moister types and the driest types in Burma in which fire-

¹ Working Plan for the Maingtha, Kunchaung, and Nanme Reserves, Ruby Mines Division, H. L. P. Walsh, 1906.

² *Dendrocalamus Hamiltonii*.

³ *Cephalostachyum pergracile*.

⁴ The protection of these forests is described by the writer of the working plan as ' a gigantic experiment which has cost half a lakh of rupees '.

protection ceases to be injurious and commences to be beneficial to the natural reproduction of teak. That stage, however, still remains to be determined.

Some examples of natural reproduction. Prolific natural reproduction of teak often springs up on abandoned shifting cultivation. This is to be seen in certain localities in the Indian Peninsula, notably in the Melghat, and is frequently observed in Burma, where abandoned *taungya* clearings often become covered with a thick and even-aged growth of almost pure teak, in many cases resembling a well-stocked plantation.

The following extract from the annual forest report of Burma for 1915-16, referring to unclassified forest adjoining the Nansaung reserve in the Mansi forest division, describes a condition of affairs often met with under similar conditions in Burma : ' *Taungyas* have been freely cut in this excluded portion, and the result has been that wherever the clearings were made the natural regeneration of teak is splendid, and we have patches of teak varying in age from two years to thirty which are as good as some of the best plantations in the Tharrawaddy division, and this without any expenditure at all.'

In Upper Burma the origin of pure even-aged natural crops of teak, other than those on alluvial bends of streams, may in a large number of cases be ascribed to abandoned cultivation, and there is little doubt that the Mohnyin forest of Katha, consisting in places of pure teak of large dimensions, originated on land which went out of cultivation during the conflicts between the Burmans, Shans, and Chinese towards the end of the sixteenth century. The main factors which appear to favour the reproduction of teak on abandoned cultivation are (1) the great vitality of the seed, which may accumulate and remain dormant in the soil for years prior to the clearing of the forest for cultivation : (2) the clearing and burning of the forest and undergrowth and the cultivation of the ground, with the consequent aeration of the soil and the admission of the sun's heat and light, and the eradication of weeds : (3) subsequent annual burning—since these areas are not fire-protected—which favours the teak against competitors.

The remarkable effect of complete clearing followed by weeding, in the stimulation of natural reproduction, is illustrated in the regenerative operations carried out in the Mohnyin forest, and described on p. 752 (see Figs. 287 to 290). At Nilambur the clear-felling of mature teak plantations and the burning of débris are followed by abundant crops of natural teak seedlings which spring from seed lying dormant in the ground.

A remarkable instance of profuse natural reproduction is to be seen in a plantation of teak, mixed in places with sissoo, on well-drained alluvial ground at Ramgarh in the Gorakhpur district, United Provinces. This locality is well outside the natural habitat of the teak, and the trees are not particularly good specimens as regards either size or shape. The plantation was formed in 1873-4, and natural reproduction had already begun to appear before 1893, when the plantation was under twenty years old. At present wherever there are openings in the canopy, dense thickets of young teak of all sizes up to over 20 ft. in height are to be found. Figs. 277 and 278, the former showing young plants up to 3 ft. high, and the latter older plants, give an idea of the remarkable profusion with which reproduction springs up where the cover is sufficiently light. The chief factors which have caused this reproduction,



FIG 277 Dense natural reproduction of teak chiefly 2 to 3 ft high in a teak and sissoo plantation
40 years old Rungtari Gorakhpur United Provinces sissoo trees girdled to admit light



FIG. 278 Dense natural reproduction of teak in a teak plantation 40 years old,
Ramgarh, Gorakhpur, United Provinces.

which is unusual in plantations, are probably a soil consisting of well-aerated and well-drained sandy loam, comparative absence of heavy weed-growth, and the open nature of the plantation, which contains fairly large gaps.

Bamboos play an important part in connexion with teak reproduction, particularly in Burma, where the nature of the bamboo growth exercises a marked effect. Thus under the heavy shade of a dense growth of *Bambusa polymorpha* or *Oxytenanthera albociliata* natural reproduction is rendered impossible owing to the heavy shade, while under the lighter shade of *Dendrocalamus strictus* or *Cephalostachyum pergracile*, or where bamboo extraction or elephant grazing has reduced the canopy of the bamboos, reproduction is sometimes plentiful. The periodical flowering and dying of the bamboo, provided the forests are not fire-protected, is known from actual observations in Burma to exercise a marked stimulus on the establishment of teak reproduction. Measures for aiding the reproduction of teak in bamboo tracts are described on pp. 756 to 761.

ARTIFICIAL REPRODUCTION. The question whether or not the formation of teak plantations is justifiable on silvicultural or financial grounds has on occasion been the subject of discussion. Opponents of the policy declare that plantations are silviculturally unsound, since teak is not naturally a gregarious tree, and that plantations are more exposed to insect attacks than teak in natural forest; again, plantations were curtailed in Burma some years ago on the ground that the staff and labour available were insufficient to cope with the work of thinning extensive areas of plantation. It is true that teak is not usually gregarious, though pure crops sometimes spring up on alluvial flats and on abandoned cultivation, but if pure plantations are objected to, mixtures are always possible. Plantations are no doubt more liable to insect attacks than isolated trees; yet although the Nilambur plantations are regularly defoliated, they have nevertheless proved a great financial and silvicultural success. On the other hand, it is by no means certain that the mixing of teak with other species can always be relied on to prevent insect damage; it is certainly disproved by a case recorded from North Vellore in 1917,¹ in which a group of 15 teak trees planted in the midst of mixed forest were attacked by *Pyrausta*, every leaf being skeletonized and the caterpillars being found everywhere; there were no other teak trees within miles. In Burma the so-called bee-hole borer is a more serious menace than these defoliators, and if some effective means of dealing with the pest cannot be devised it may be advisable to mix the teak with other species or to limit the size of the blocks to be planted with teak, separating them by fairly wide belts of natural forest or by plantations of other species.

Mr. C. F. C. Beeson has found that attacks of bee-hole borers are worse in pure plantations than in mixed forests rich in teak; he has also found that a dense undergrowth of bamboos, and particularly of *Bambusa polymorpha*, acts protectively, lessening the severity of the bee-hole attack. The borer can, according to Mr. Beeson, be dealt with to some extent in the conduct of thinnings. Thus (1) if trees marked in thinnings are felled before the end of the year, the borers in those trees will die; (2) the removal of dominated and suppressed trees not required in the crop removes a considerable proportion

¹ Conservator of Forests' Inspection Note, 1917.

of borers; (3) the earlier the thinnings are commenced and the shorter the intervals between them, the lower will be the incidence of the borer.

The labour question is certainly a difficulty in some localities, and plantations have to be limited accordingly, but the want of an adequate staff cannot be taken seriously as an excuse for not forming plantations, since the remedy is obvious. It has been held that plantation teak is inferior in quality to natural teak, but Mr. Pearson has carried out two separate series of tests with plantation teak from Burma, in both of which it was found that the timber was in point of strength in no way inferior to natural teak.

Wherever conditions are suitable, on the other hand, there are strong arguments in favour of teak plantations. It is obvious that land which is made to yield, say, 40 mature teak trees per acre after about 100 years or less is being utilized to much greater advantage than the same land which under natural conditions yields only a few mature trees per acre in 150 years or more. Again, the cost of tending, upkeep, and supervision for a given number of trees is much reduced by the concentration of work possible in the case of plantations, and this results in more rapid growth and a considerable reduction of the rotation, which means a great financial gain. Experience in Burma has shown that *taungya* plantations formed on correct lines cannot be approached for cheapness as a means of increasing the stock of teak, and that the financial prospects of such plantations are decidedly good. Finally the financial results of the Nilambur plantations, quoted below, should remove any doubts as to the desirability of forming teak plantations, always provided care is taken regarding important details such as the choice of site, the extent of area planted, the method of formation, a suitable mixture of species or isolation of planted blocks where the attacks of insects, and particularly the bee-hole borer, are to be feared, careful tending throughout the life of the plantation, and other matters.

Particulars of some teak plantations. Teak plantations have been formed to a greater or less extent in many parts of the natural region of this tree as well as in localities outside its natural habitat. A short account of some of these plantations may be of interest.

Central Provinces. Small plantations exist in various districts. In the Sipna valley of the Melghat forest division of Berar about 1,000 acres were planted between 1868 and 1879.

Bombay. A good deal of planting has been done from time to time in different localities. The earliest plantations formed were those at Sulgeri, Kadra, and Mardi in the Kalinaddi valley in North Kanara. The Sulgeri plantation was started in 1867-8, and continued until 1881-2, by which time the area amounted to 410 acres. The Kadra plantation was commenced about 1865 or 1866, and continued until 1881-2, when the area aggregated about 200 acres. The Mardi plantation was commenced in 1869-70, and an area amounting to 102 acres was planted at different times. The spacing was 9 ft. by 9 ft. The success of these plantations has been variable. Most of the planted area is on laterite, with very shallow soil in places, and here the growth is poor or complete failure has resulted. The plantations also appear to have suffered from want of tending in the earlier years, and from the fact that thinnings were too long delayed. Considering that much of the area has

proved a failure, the cost has been extravagantly high ; the expenditure on the Kadra and Mardi plantations up to 1908-9 is reported to have been as much as Rs. 150 per acre, while the receipts amounted to Rs. 16 per acre.

Madras. Teak plantations have been formed from time to time in various parts of Madras, but by far the most important plantations are those in the Nilambur valley in South Malabar. The Nilambur plantations owe their inception to the foresight of Mr. Conolly, Collector of Malabar, who in 1840 foresaw the shortage of teak likely to occur through the depletion of the natural forests, and urged the formation of teak plantations in the Nilambur valley, a proposal which was approved by Government. After three years of experimental work, regular clear-felling of the existing forest and planting with teak was started in 1844 ; this work has been continued more or less steadily ever since, though no planting was done from 1877 to 1885. The total area planted up to 1918 was approximately 6,500 acres.

The Nilambur valley is an ideal situation for teak plantations. The plantations are situated at an average height of about 100 ft. above sea-level. The valley is surrounded on three sides by hills, of which the highest, the Nilgiris, rise to 8,000 ft. The village of Nilambur itself is about 45 miles by road from the coast. The normal rainfall at Nilambur is 109 in., and the shade temperature varies from 80° to 90° F. throughout the year. Over much of the area the soil is a deep fertile well-drained alluvium admirably suited for teak ; this is interrupted at intervals by patches of laterite, often in the form of low hills or undulations. Between the best alluvial soils and the laterite, various gradations of soil occur. The laterite produces teak of poor quality, and in many places the teak has failed altogether ; hence it has been decided, as a result of the experience gained, to avoid planting on laterite areas of poor quality during the second rotation. The Nilambur valley is drained by a good floating-stream which flows into the sea at Beypore, immediately to the south of Calicut, and the outturn of the plantations can be delivered at the coast at the low cost of 2a. 6p. per cubic foot, inclusive of all charges. Much of the timber finds its way in small trading vessels to Persia and Arabia, where poles as well as larger timber are much in demand. Planting has been carried out in large contiguous blocks, and hence the Nilambur plantations have not had to contend, so far as cost of upkeep goes, with the adverse conditions from which so many of the Burma plantations have suffered by being scattered in small isolated patches amidst natural forest.

The Nilambur plantations have proved a conspicuous financial success. In 1912 the financial results to date were worked out, and it was ascertained that after allowing 4 per cent. compound interest on all receipts and charges the total revenue, expenditure, and surplus amounted respectively to Rs. 56,22,090, Rs. 54,79,531, and Rs. 1,42,559 ; the total planted area was then roughly 6,000 acres. The rotation has recently been fixed at seventy years, and the final fellings of the first rotation have already begun. The net surplus for the year 1917-18 was Rs. 2,75,532 for the 6,500 acres planted, or Rs. 42.4 per acre per annum ; the future surplus is estimated to be over Rs. 30, and may possibly reach Rs. 40 per acre per annum. The results would have been even better but for the fact that the planted area contains a certain proportion of laterite outcrops and badly-drained ground where teak has failed.

Average figures of outturn for the Nilambur plantations will be found below in the yield table (p. 763) given under 'statistical'. In 1917 the largest teak tree in the plantations had a girth of 9 ft. 8 in. and a height of 135 ft.; it was situated in one of the earliest plantations, in the Iruvallikava block.

Figs. 279 to 283 show typical examples of plantations of various ages at Nilambur.

Coorg. The oldest teak plantation in Coorg is the Karmad plantation, started in 1868 and extended gradually till 1875. Its total area is 197 acres, of which in 1918 about 120 acres were estimated to be fairly well stocked with teak. The formation of this plantation does not appear to have been carried out on correct lines, in that the existing forest growth was incompletely felled, and the plantation suffered for many years from the presence of overhead trees; cleanings and thinnings were also neglected to some extent. The total expenditure on the plantation from 1868 to 1918 amounted to Rs. 26,948, or Rs. 136 per acre. *Kumri (taungya)* plantations were started in 1891, and have been continued subsequently; many of these are very thriving, though some have suffered for want of tending. These plantations have been raised from nursery transplants, but latterly direct sowings under the Burma method have been tried with good results.

Travancore. Bourdillon states that teak plantations were commenced in Travancore in 1866-7, and have been gradually extended since then, the aggregate area in 1908 being 2,666 acres. He mentions that the final fellings are expected to be made in the ninetieth year; also that it has been calculated that after charging 4 per cent. interest the sale of thinnings will pay off all expenditure by the seventieth year, and that at the time of the final felling in the ninetieth year there will be a balance to the good of Rs. 6,887 per acre, representing an annual profit of Rs. 76.6 per acre from the commencement.

Burma. Teak plantations were commenced in Burma in the fifties of last century, one of the oldest being the Thinganninaung plantation on the upper Winyeo river (Ataran) in Tenasserim, which was started about 1856. Several of the older plantations are associated with the name of Dr. Brandis. Among these may be mentioned the Myodwin plantation situated on flat alluvial ground about ten miles east of Zigôn in the Tharrawaddy district. It was extended subsequently in 1885-6, and again about 1904. The old plantations were formed by clearing and burning the existing jungle and digging up the ground; in 1862 seed was sown in lines 6 ft. apart, in 1863 nursery transplants were put out 3 ft. by 10 ft., and in 1864 seed was sown 3 ft. by 10 ft. The plantation of 1904 was formed under the *taungya* system, seed being sown with a spacing of 6 ft. by 6 ft. Another plantation formed by Dr. Brandis is that of Kangyi, about six miles east of Zigôn; this plantation, which is also situated on alluvial ground, was formed in 1864-5, and has produced a girth increment of at least 1 inch per annum. Another old plantation is that at Kywemakaing in the Kadinbilin reserve, Tharrawaddy. It was commenced in 1867, when an area of 58 acres was planted, and in 1869 it was increased by 86 acres, making a total of 144 acres. The spacing was chiefly 6 ft. by 6 ft., with a small area 10 ft. by 4 ft. This plantation is on hilly ground, and although the success varies it is good on the whole. It has proved expensive, since the original forest was felled and burnt departmentally without any

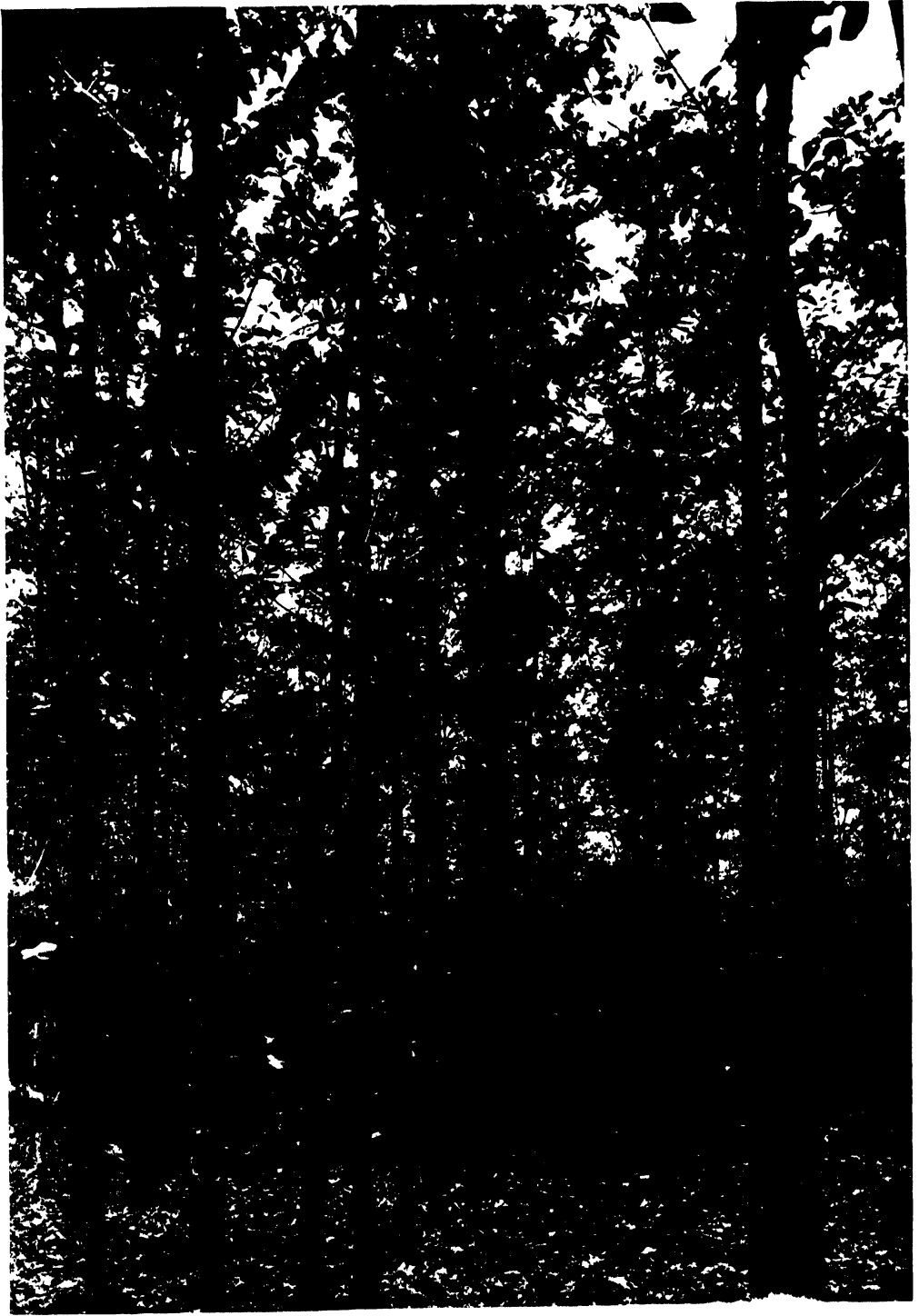


FIG 279. Teak plantation 14 years old, Ramalur block, Nilambur, South Malabar

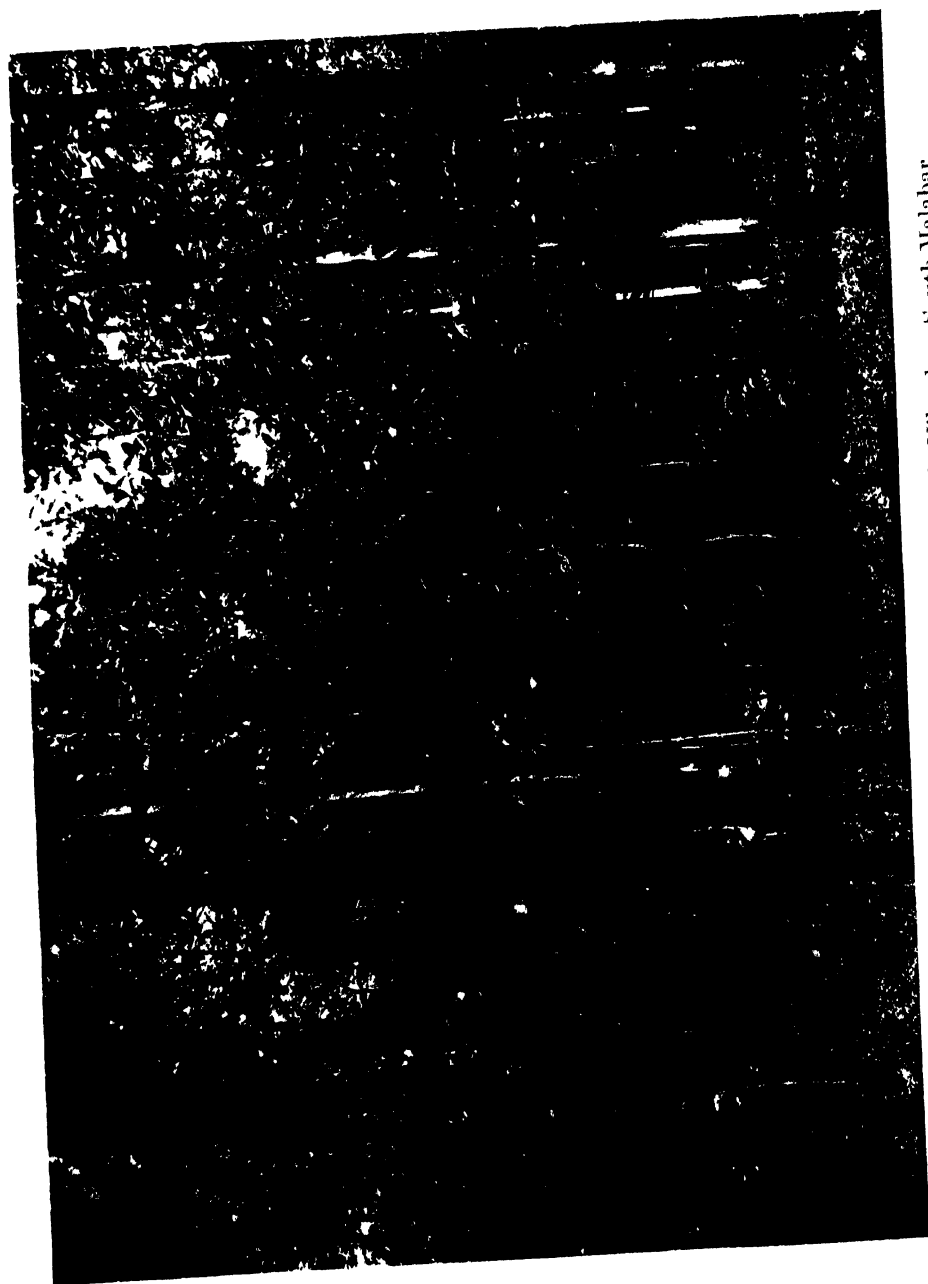


FIG. 280 Teak plantation 20 years old. Edacode block, Nilambur, South Malabar

cultivation of field crops. The cost amounted to Rs. 112 per acre up to 1884, and Rs. 120 per acre up to 1904.

The earlier Burma plantations were formed without the aid of field crops, and have accordingly been designated 'regular plantations'. The idea of combining the raising of teak with the practice of shifting cultivation (*taungya*), so prevalent among the jungle people of Burma, originated with Dr. Brandis, though the credit of applying it in its practical details in the Tharrawaddy forests appears to belong to Colonel W. J. Seaton, who was in charge of those forests from about 1863 to 1870. *Taungya* plantations were commenced in Tharrawaddy on a small scale in 1869, and since 1873 have been extended almost continuously. These plantations have proved a cheap and efficient means of raising teak plantations on a large scale, and are admirably adapted to the habits of the jungle population. They have been formed extensively in many parts of Burma. In 1917 the total area of teak plantations, including 6,021 acres of teak mixed with cutch (*Acacia Catechu*), was 71,731 acres, of which no less than 68,364 acres consisted of *taungya* plantations.

Details regarding the method of formation and tending of *taungya* plantations, with figures of cost, are given below. The mistake of scattering these plantations in small isolated blocks is referred to on p. 735; but for this mistake the potential value of the teak plantations of Burma as profit-earning concerns would be much higher than it is. There is nevertheless a great future before the *taungya* system in Burma, provided definite concentrated blocks of forest are set aside for planting up under regular schemes; in particular the conversion of blocks of evergreen or semi-evergreen forest into profitable teak plantations holds out considerable promise. The labour difficulty might be got over where possible by the establishment of forest villages; the necessary increase of staff for purposes of supervision could well be justified on financial grounds wherever the choice of site has been carefully made. Perhaps the only serious obstacle to the extension of teak plantations, as far as labour conditions will permit, is the risk of encouraging the spread of the bee-hole borer. This danger is sufficiently real to form a valid reason for avoiding pure plantations of teak over large areas and for finding suitable species for growing in mixture with the teak.

United Provinces. The plantation at Ramgarh in the Gorakhpur district, which has regenerated itself in a remarkable manner, has already been referred to. Recently teak has been tried in connexion with afforestation work in ravine lands in the Etawah district, and has shown rapid growth in the earlier years. Teak trees are planted, and grow moderately well if they escape frost, as far north as Dehra Dun. There is a small plantation at Lachiwala in the Dun, but it has been cut back repeatedly by frost, and may be regarded as a complete failure.

Bihar and Orissa. Within recent years teak plantations have been formed in the Puri district.

Bengal. There is a plantation at Bamunpokri in the Darjeeling *tarai*, and a small one, dating from 1869, in the Lower Tondou forest near Gorumara in the Jalpaiguri district; both of these have succeeded fairly well. The latter was at one time reported to be a failure, but when I visited it in 1915 I found it looking healthy, although it appeared to have suffered from want

of early tending. It is situated on well-drained sandy loam along a high bank ; the rainfall here is about 160 in., and frost is unknown. At the time of my visit it was 46 years old, and the trees were found to have an average and maximum girth of 3 ft. 9 in. and 5 ft. 4 in. respectively, omitting suppressed stems, which is a fair rate of growth. The Sitapahar plantations along the Karnafuli river in the Chittagong hill tracts were commenced in 1872 and continued in subsequent years, but a severe cyclone in October 1897 devastated the plantations and destroyed a large proportion of the trees ; within recent years further plantations have been formed under the *taungya* system in this locality, and plantation work is being continued on a fairly large scale.

Assam. The Kulsi teak plantations in the Kamrup district, formed in 1872 and following years, have done well ; there is also a plantation at Makum near Dibrugarh.

Andamans. Teak plantations in the Andamans were started in 1883 and continued spasmodically. From 1883 to 1889 teak and padauk (*Pterocarpus dalbergioides*) were raised in mixture, but the former outgrew and suppressed the latter. The teak has done well both on padauk soil and on evergreen soil, but rather better on the former than on the latter. The cultivation of teak promises to be highly successful, and to be more remunerative than that of the indigenous padauk ; the growth is nearly, if not quite, up to the average for Burma. The earlier plantations were formed by transplanting from the nursery, and the later ones by direct sowing.

Arakan. There is a small plantation dating from 1825 on the Thade stream behind Sandoway. In 1915 there were 106 trees in it, of which seven were over 7 ft. in girth, the largest being 12 ft. 3 in. in girth. A plantation formed about the same time in the plains near Taunggök in the Sandoway district is reported to have been a failure. There is a plantation in the Uthalin valley dating from about 1870. In the Akyab subdivision there are numbers of small plantations formed between 1872 and 1875. In 1918 the number of plantations dating from before 1900 was about 100, aggregating 195 acres, the largest being 32 acres, while many of them were less than 1 acre in area. From 1900 onwards plantations have been extended considerably, and on suitable well-drained sites the growth is good.

Choice of site. The importance of careful selection of sites for teak plantations has not always been fully realized. Perhaps the most essential factor is good drainage, since badly drained ground, or ground liable to inundation for many days at a time, is totally unsuitable for the growth of teak. Laterite should be avoided if the rock is anywhere near the surface ; this is well illustrated at Nilambur, where the plantations formed on low laterite hills have not produced anything but small-sized trees, and in many cases have proved an entire failure. Similarly poor shallow soil should be avoided, since although teak can persist on such ground the trees remain stunted, and plantations formed in such localities cannot be expected to prove financially successful.

Teak can be grown successfully on ground which is not naturally teak-producing, even within its habitat. Some of the most promising teak plantations in Burma have been formed on ground which previously supported evergreen forest. The soil of tropical evergreen forest being particularly fertile, the growth of the teak on such ground is often very good ; the growth

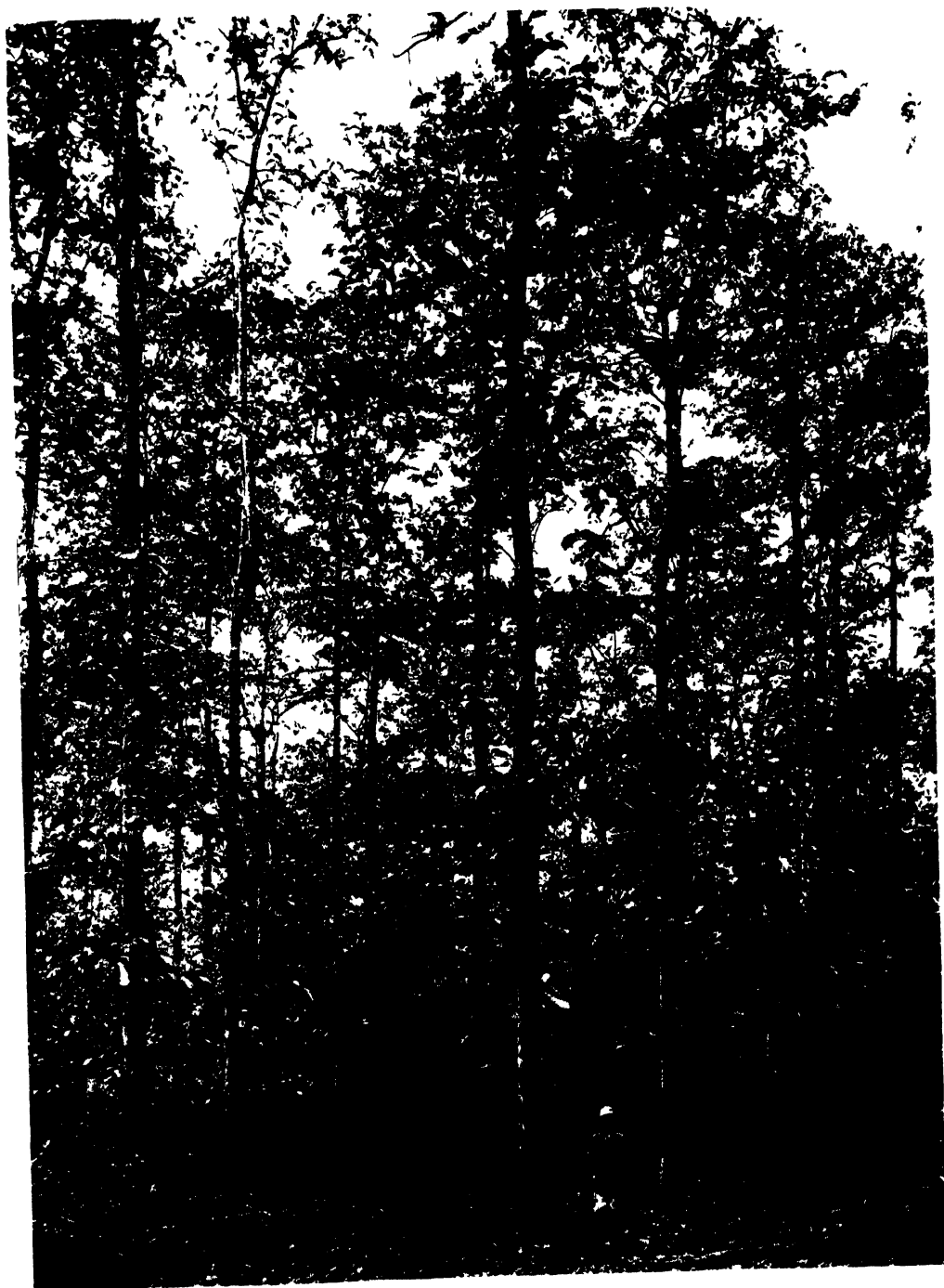


FIG. 281 Teak plantation 54 years old. Elanjery block, Nilambur, South Malabar



FIG. 282. Teak plantation 57 years old. Panengo de block, Nilambur, South Malabar.

of weeds and climbers is likewise luxuriant, and hence weedings and cleanings in plantations on ground formerly occupied by evergreen forest are a specially heavy item. Plantations can be formed with great success on well-drained alluvial ground, as witness some of the plantations of Burma and Nilambur ; early prognostications notwithstanding, the trees on such ground have satisfactorily maintained their soundness throughout their life, and are in some cases approaching maturity. On alluvial ground, however, great care is necessary to carry out repeated climber-cutting operations, as climbers often grow in great profusion in such places. Savannah lands are, as a rule, unsuitable for the formation of teak plantations.

The size of a teak plantation is, from a financial point of view, a matter of great importance. In Burma, with its wealth of plantations, a cardinal mistake has been made in scattering these in numerous isolated patches, some only one or two acres and others several acres in extent, in the midst of natural forest. Many of these have been lost sight of, and have perished owing to the rapid encroachment of the surrounding bamboos and jungle. Those which survive have been saved only at the cost of periodical cleaning of their boundaries at frequent intervals, the surrounding jungle being thus kept at bay. In the case of small scattered plantations the cost of such work soon outweighs any possible return to be derived ultimately from the plantation ; on this account many of the Burma plantations must be written down as a financial loss, while many of the smaller plantations have disappeared entirely, their site being marked only by the remains of the boundary-boards, which serve the purpose of tombstones. In a moist climate like that of Burma, where any clearing is quickly invaded on all sides by the luxuriant surrounding forest growth, and where the boundaries of plantations have to be repeatedly cleared, it is well to fix a minimum area to plant up in the course of one or more years in one self-contained block. Only by this means will the boundary be short enough, in comparison to the area of the plantation, to bear the cost of periodical clearing. In Burma this minimum area was fixed some years ago at 25 acres. In this respect the Nilambur plantations have been formed on sounder lines than the majority of the Burma plantations, as they are for the most part comprised in blocks of considerable extent. This defect in the Burma plantations has been due largely to an exaggerated notion that no forest should be cleared for the formation of plantations which contains any teak trees. This argument, however, can hardly hold in view of the fact that in place of a few scattered teak trees the ground will be made to support perhaps forty trees of valuable species to the acre at maturity, allowing for a suitable mixture of other trees besides teak where the bee-hole borer is to be feared. The sparing of a few isolated teak trees can certainly never justify the financial loss involved in scattering the plantations in small isolated blocks. In dry climates such as those met with in many of the teak-bearing tracts of the Indian Peninsula, this rule regarding the size of plantations would not hold to the same extent, if at all, except in so far as concentration for purposes of tending and upkeep is concerned.

Spacing. The spacing now almost universally adopted in Burma is 6 ft. by 6 ft., this giving even growth all round and being close enough to produce a complete canopy in a few years. In the earlier plantations in Burma spacings

of 12 ft. by 3 ft. and 9 ft. by 4 ft. were common ; the plants are thus fairly close together along definite lines, and weeding is facilitated, but the canopy takes longer to close up than in 6 ft. by 6 ft. spacing. In the Tharrawaddy plantations of 1876 and 1877 belts of teak consisting of three lines 6 ft. apart, each belt separated by an unplanted strip 30 ft. wide, were tried ; in 1878 wider belts were formed, eight lines 6 ft. apart being planted, and unplanted strips 30 ft. wide being left between the belts. This system was apparently found unsatisfactory, as it was discontinued.

In the Nilambur plantations a spacing of $6\frac{1}{2}$ ft. by $6\frac{1}{2}$ ft. has been the general rule ; a spacing of 6 ft. by 6 ft. was adopted for a time prior to 1904, but it was afterwards decided to plant with a spacing of 8 ft. by 8 ft. on first-class soils and 6 ft. by 6 ft. on second-class soils. Wide spacing, however, has now been given up, and the rule in recent years has been to plant $6\frac{1}{2}$ ft. by $6\frac{1}{2}$ ft. on soils of good quality, and 6 ft. by 6 ft. on soils of poorer quality. Although wide spacing is more economical than close planting, reckoning the cost of planting an acre at a given rate per plant, at Nilambur it is said to have resulted in a fair proportion of the trees being forked at a height of 20 to 25 ft. from the ground. Mr. P. M. Lushington, again, notes that the extra cost of close planting at Nilambur is recovered from the first thinnings, and that close spacing has a great advantage in producing straight clean stems. Another result of wide spacing is that weedings have to be continued longer, and give more trouble, than in the case of close planting, so that expenditure saved in the cost of formation has to be added to the cost of tending. This was found to be the case in Coorg, where a spacing of 10 ft. by 10 ft. was tried at one time, but was discarded owing to the trouble given by weeds. In Travancore a spacing of 15 ft. by 15 ft. was tried during the first few years of plantation work, but this was afterwards discarded for a spacing of 5 ft. by 5 ft. or 6 ft. by 6 ft.

Preparation of seed. In most parts of India it is customary to subject teak seed to some form of preliminary preparation in order to hasten germination, without which the seed is found to lie dormant for a year. Provided the seed is sown well before the early showers preceding the monsoon, such preparation is not always necessary ; it is not ordinarily resorted to in Burma, and the results are all that can be desired. In India many different plans are adopted. At Nilambur soaking for 48 hours before sowing in the nursery is found to give good results ; the soaking is effected by placing sacks of seed in running streams. Exposing the seed to the weather for a whole year in the open has been found successful in Bombay. In Kanara seed sown in beds early in April, and watered daily until the rainy season, has been found to germinate fairly well, though some of the seeds lie dormant for a year. Mr. L. S. Osmaston¹ has described a method which has given uniformly excellent results in Satara, where the rainfall is about 24 in. A hole large enough to hold all the seed is dug in April in a sunny spot, filled with seeds, covered with a layer of earth 1 in. thick, and thoroughly drenched with water every third day for six weeks. The seed is then taken out and spread in the sun for three weeks, by which time the rainy season is about to commence, when the seed is sown and germination takes place readily. Another plan, successfully tried in Surat, is to

¹ Ind. Forester, xxxiv (1908), p. 534.

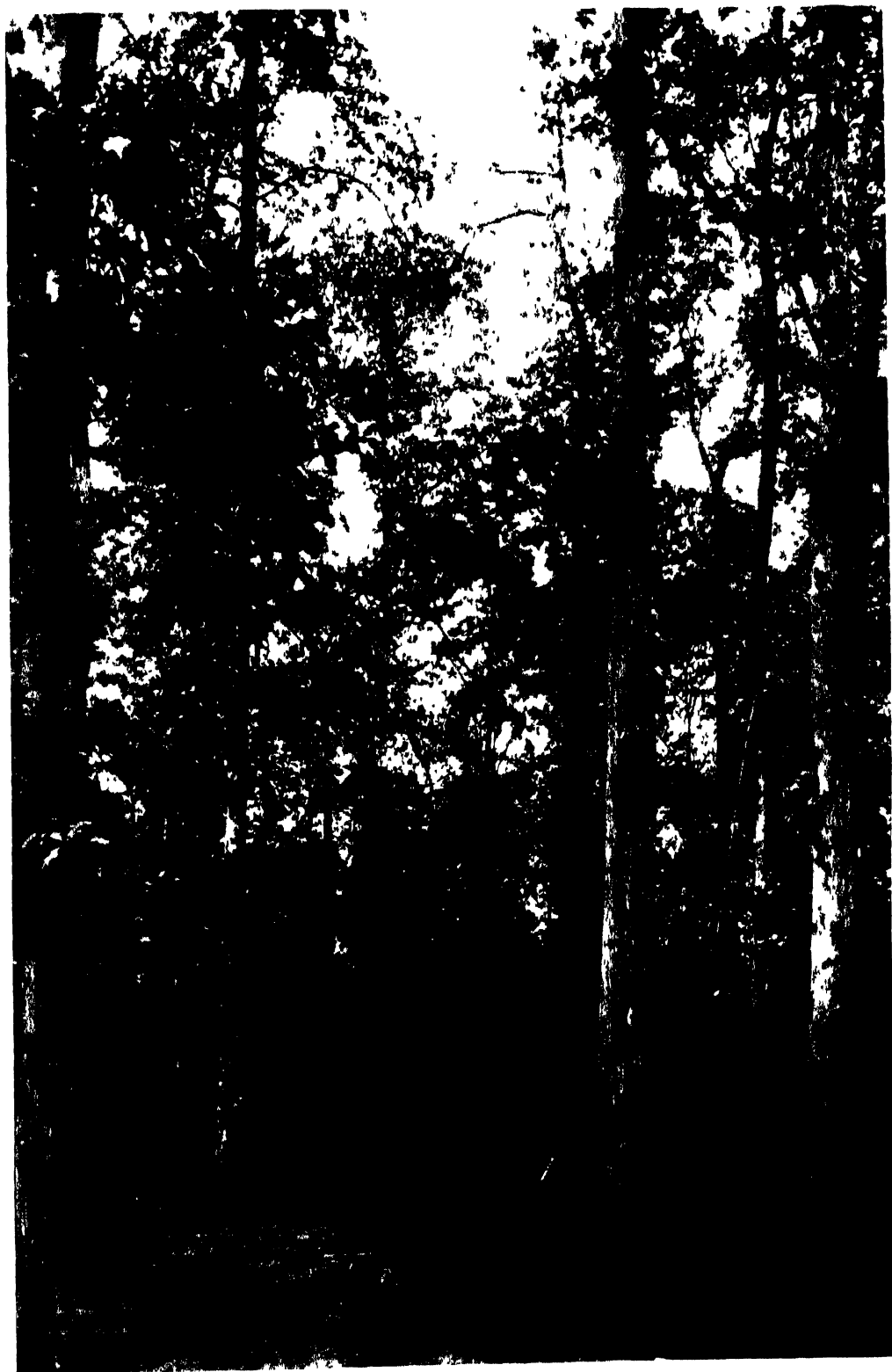


FIG. 283 Teak plantation 65 years old, Moolathamano block, Nilambur, South Malabar : tree with man at base 7 ft. 8 in. in girth.



FIG 284 Young teak *tanjung* plantation in second year. Burma.

subject the seed to alternate soaking in water for twenty-four hours and drying on the ground for four days, repeating this process for a fortnight ; the seed is then placed in a hole in the ground and kept moist until germination begins, when the germinating seeds are removed daily and sown. Slight charring has been found to stimulate germination, but this method is not to be recommended, since the vitality of the seed is destroyed if the heat is too intense. Mr. E. M. Hodgson¹ in Surat found that soaking for twenty-four hours in lukewarm water prior to sowing invariably induced germination in twelve to twenty-four hours. A method which is said to give good results in Bombay is to fill a pit with alternate layers of seeds and earth 1 in. thick, cover it with earth, and keep it well drenched with water for about a fortnight ; the seeds and earth are then mixed well together and watered until germination begins. A method tried with success in Ceylon is to spread the seed in a layer 4 in. thick on a mat in the sun and keep it constantly watered ; germination starts in about three days, and the germinating seeds are removed daily and sown in the nursery. This method should be carried out only in fine weather, since the seeds are apt to rot if kept too moist without being exposed to the sun. In an experiment carried out by Mr. H. Tireman in Coorg in 1916 good results were obtained by placing the seeds between gunny-bags in April and watering them well ; germination commenced in 13 days, and ceased 26 days later.

Covering of seed. The depth to which seed, whether sown in the nursery or direct in the forest, should be covered with earth is a matter of some importance. A number of experiments which I carried out at Dehra Dun, in which seed was covered to various depths up to 2 in., showed that the best results are obtained by covering it to a depth of less than $\frac{1}{2}$ in. These experiments were repeated several times, and the result obtained in each case was the same.

Nursery treatment and transplanting. Teak may be raised either by direct sowing or by the transplanting of seedlings which are raised as a rule in the nursery ; the former method is the more usual in Burma and the latter in India, though direct sowings appear to have come more into vogue in India within recent years. The methods of raising teak seedlings in the nursery vary in detail. Seedlings may be transplanted the year of sowing or may be kept in the nursery for a year. In the former case any injury to the root should be avoided, and small-sized seedlings should therefore be used, but in the latter case the plants will stand pruning of the taproot, provided the stem is also pruned down.

The method which has been employed for raising most of the plantations in the Nilambur valley is as follows :

Seed-beds are formed near the area to be planted ; good free soil is selected, dug to a depth of 3 ft. and broken into fine mould, after the removal of weeds, roots, and stones. An edging 3-4 in. high is constructed round the beds, which have a width of about $2\frac{1}{2}$ ft. between edgings. The seed is collected in February from vigorous trees and sown about the 7th to 15th April ; before being sown it is soaked for 48 hours in water. About 240 lb. of seed, sown broadcast, suffice for 150 ft. length of bed. The seeds are covered with earth to a depth of $\frac{1}{2}$ - $\frac{3}{4}$ in., and the beds are then covered with straw, a few leafless

¹ Ind. Forester, xxvi (1900), p. 279.

twigs being placed below the straw to prevent it from mixing with the earth ; the object of the straw is to prevent the earth from being washed off the beds when watering is in progress. The beds are watered copiously every day, and germination takes place in 10–20 days, when the straw and twigs are removed. Thereafter watering is carried out more sparingly as the plants become stronger. The monsoon sets in, as a rule, in the beginning of June, and it is of the greatest importance that the seedlings should be of the correct size, that is, about 3 in. high, with two pairs of leaves besides the cotyledons ; the third pair of leaves are usually a good deal larger, and if they have appeared they should be nipped off. The larger plants are discarded in favour of those about 3 in. high. Planting should always be carried out during continuous rain ; if this is not done, or if there is a break of a few days after planting, much failure results. Planting should be completed as early in the rainy season as possible ; in this case the seedlings reach a height of several feet by the end of the season, while those put out late show poor development. If late planting is unavoidable, small seedlings which have germinated late are selected in preference to larger ones with long thick taproots. The planting site is felled in December, the felled material being allowed to dry until March, when it is burnt, the unburnt logs being then cross-cut, piled, and again burnt. Lining is then carried out, and after the ground is softened by rain pits 10–12 in. cube are dug and filled in with the loose earth, in which the planting hole is made with the hand or with a bamboo stick at the time the seedling is planted ; the earth is then replaced round the roots and pressed well down, care being taken not to place the seedling in a hollow, but rather to raise it slightly above the surrounding level of the ground, in order to allow for the settling of the earth.

Under this system the cost of formation is somewhat high. Mr. J. Ferguson, who was in charge of the Nilambur plantations for many years, made out the following statement of the average cost per acre of clearing and planting on forest land :

	Rs.	a.	p.
Weeding undergrowth preparatory to felling	2	0	0
Felling	5	0	0
Firing after felling	0	4	0
Cross-cutting remains of first burning	3	8	0
Piling and burning off clear	10	0	0
Lining, marking, pitting, and planting out	3	8	0
Weeding and hoeing round the plants	2	8	0
Second, third, and fourth weedings at Rs. 1–4–0 each	3	12	0
Collection of teak seed	0	8	0
Preparing, sowing, and watering nursery beds	3	0	0
Contingencies	2	0	0
Total	36	0	0

This does not include the cost of superintendence. The average cost of formation is now usually reckoned at Rs. 40 per acre for complete establishment up to the first thinning. Pruning is carried out only in the case of unligified branches of young plants up to three years of age ; these often develop forked stems or produce strong side branches which may be pruned off with advantage.

In some localities, particularly in parts of Bombay, it is customary to

keep the seedlings for a year in the nursery before planting them out. The seedlings are usually pricked out 6 in. apart in the nursery about June or July of the first year, when 2 or 3 in. high, weeded regularly and watered in dry weather, at first frequently and later as sparingly as possible. They are planted out early in the following rainy season, when about a year old, the stem being, as a rule, pruned down to about 2 to 3 in. from ground-level and the root being trimmed.

A plan which has been adopted in some places is to sow the seed in the nursery beds about the beginning of the rainy season and to do no watering until about February or March the following year; this induces germination within a short time, and the plants reach a height of about 9 to 12 in. by the beginning of the rains, when they are planted out.

Transplanting natural seedlings. The transplanting of natural forest seedlings, to supplement dibblings, has been carried out with success in the Katha district of Upper Burma. A remarkably successful experiment was carried out several years ago in the Tharrawaddy forests by Ranger Maung San Lon. He cleared and burned a small patch, and in it planted the thickened root-stocks of young natural teak plants which had been killed back repeatedly by fire or suppression; the stems were pruned down, the roots were trimmed, and the thickened root-stocks were planted somewhat after the manner of potatoes. The result was a flourishing plantation of vigorous plants.

Ranger J. D. Rego¹ has described the success attending the transplanting of natural teak seedlings in the Mundgod pole forests of North Kanara, particularly in patches where the refuse of fellings had been burnt. It was found that natural seedlings dug up and transplanted showed better growth, probably owing to the loosening of the soil, than natural seedlings left *in situ* and tended by mulching in the manner already described on p. 723. For this purpose small seedlings 2 to 3 in. high are found to be best; these are found in large numbers at the beginning of the rains on fire-lines and roadsides, and the supply is augmented by creating small nurseries in the coupes by burning leaves and brushwood and sowing seeds on the burnt patches. The best results of all are attained by transplanting seedlings into burnt patches, in which case they attain a height of 1–2 ft. in the first year, and no weeding is necessary. Seedlings planted on unburnt ground require weeding for two and sometimes for three years. The method of burning adopted is to collect all the brushwood and felling refuse into heaps, which are burnt during the hot weather immediately after a shower of rain, when there is little fear of the fire spreading.

The Burma taungya system. This is the system which has been almost universally employed in Burma for many years past, and has proved a most efficient and economical method of forming teak plantations. It consists in dibbling teak seed along with field crops in temporary forest clearings and tending the crop of teak after the field crops have been reaped. One of the most important operations connected with this system—and the same applies to any system of clearing forest land for plantation purposes—is to secure as complete and thorough a burning of the felled material as possible before sowing the crops and the teak. This is well understood by the *taungya*-cutters,

¹ Ind. Forester, xliii (1917), p. 197.

and it means all the difference between success and failure. If the burning is not thorough, half-burnt logs and stumps encumber the ground, preventing regular planting and hindering subsequent weeding. Thorough burning consumes all the felled trees and many of the stumps, as well as the seeds of weeds and climbers, prevents regrowth from felled trees and bamboos, and enriches the soil with the ashes. In order to ensure thorough burning the forest growth should be felled early in the cold season, and the felled material should be carefully protected from fire through the cold and hot seasons. It should then be burnt late in the hot season, by which time it will have become reasonably dry, but care should be taken not to delay the burning until the early showers preceding the monsoon, otherwise complete burning may be impossible. In this way a fierce conflagration results, and the felled material is thoroughly burnt ; any material which is not consumed is collected into heaps and burnt again.

As soon as the burning is finished the lining out is done, bamboo stakes being inserted in the ground at the required distances. The teak seed is then sown, three seeds as a rule being sown at each stake and very lightly covered ; the sowing should be completed before the monsoon breaks. At the same time a small nursery is made at a convenient place in the clearing from which seedlings are obtained to fill up gaps where failures occur. The field crops, which are sown about the same time, vary ; hill rice is the commonest crop, but in some localities maize, sesamum, or other crops are grown. The lines of young teak require to be kept free from suppression by the crops and by weeds ; the cultivator attends to this. About December or the beginning of January, after the field crop is reaped, the lines of teak are cleared by the cultivator—or *ya*-cutter, to give him his usual name—and all bamboo stakes which have been lost are replaced by fresh ones. An enumeration is then made of all the living plants and all the blanks or dead plants ; this enumeration is carried out under close supervision by men provided with split bamboo tallies on which each plant is nicked off in turn. Payment is made to the *ya*-cutter usually at the rate of one rupee for every hundred living plants found at this enumeration. With a spacing of 6 ft. by 6 ft. the number of plants per acre is approximately 1,210, and the cost of formation for a completely stocked plantation, including weeding during the first season, amounts to about Rs. 12 per acre. In localities where there is much demand for *taungya* land the initial cost can be reduced or even eliminated altogether. In the northern parts of Upper Burma *taungya*-cutters are paid nothing ; they do all the clearing, burning, and weeding during the first year without payment.

The system of forming *taungya* plantations varies in detail, but that just described is commonly in vogue in the forests of the Pegu Yoma. In some localities the area is cultivated for two years in succession, teak seed being sown the second year. The weeding and cleaning of *taungya* plantations is a matter of great importance, and is referred to below under 'tending'.

The cost of *taungya* plantations has varied considerably in the past, but it should be comparatively small if the work is properly carried out and supervised.

In the case of the Tharrawaddy plantations the average cost, as worked out a few years ago, is as follows :



FIG. 285. Young teak *taungya* plantation in third year. Tharrawaddy, Burma



FIG 286 Teak *taungya* plantation 9 years old, ready for first thinping, Tharrawaddy, Burma

Tectona grandis : average cost of *taungya* plantations, Tharrawaddy.

Age. Years.	Operations.	Cost per acre.	
		Rs.	a.
1	Formation	10	0
2	Weeding	2	0
3	„	2	0
4	„	1	8
		Rs. 15-8	
7	Cleaning	2	0
10	Cleaning and thinning . .	2	8
		Rs. 20	
15	Cleaning	2	0
20	Thinning	2	0
		Rs. 24	
25	Cleaning	2	0
30	Thinning	2	0
		Rs. 28	
40	Thinning	3	0
		Rs. 31	

In the more accessible plantations of Tharrawaddy the produce of thinnings begins to be saleable at an age of 20 years, and it is reckoned that the whole cost of the plantation, with compound interest to date, is recovered in 40 to 50 years ; this, however, is not the case in all the plantations either of Tharrawaddy or of other localities. Generally speaking it may be said that it ought to be possible to establish *taungya* plantations and bring them through the weeding stages up to say the fifth year, at a cost of not more than Rs. 20 per acre.

Fig. 284 gives a general view of a young teak *taungya* plantation ; Fig. 285 shows a well-stocked young plantation ; and Fig. 286 shows a plantation nine years old, ready for the first thinning.

Kumri plantations in Coorg. The *taungya*, locally known as *kumri*, method of forming teak plantations has been practised for some time in Coorg, the work being done mainly by the Kurumbars. Teak seedlings are supplied by the Forest Department, and these are planted out by the Kurumbars free of cost with their crops, which consist usually of hill rice and *ragi* (*Eleusine coracana*). The area is again burnt and cultivated a second year, casualties among the teak being replaced ; the burning is found to stimulate the growth of the teak. The Kurumbars tend the plants until they are 2½ years old, and then receive payment at the rate of Rs. 1-4-0 per hundred surviving plants ; this includes payment for the collection of teak seed.

Recently direct sowing after the Burma plan, instead of transplanting, has been tried in the *kumris* of Coorg, and the results have proved successful provided sowing is done as soon as possible after the clearings are burnt, in order to obtain the benefit of the early showers in April and May. Weedings are carried out for the first two or three years.

Line sowings with field crops. Mr. L. S. Osmaston¹ has described the results of experimental line sowings of teak and other tree species along with field crops in the dry parts of the Bombay Deccan, where the normal rainfall is about 20 in. He states that in his experience the only successful method of restocking these dry tracts is by means of agriculture combined with forestry ;

¹ Ind. Forester, xxxiii (1907), p. 265.

the success in any year, however, depends largely on the rainfall. It was found better to entrust the work to lessees than to carry it out departmentally. Two different methods were tried, in both of which a two-years lease was given; the field crops employed were sesamum, cotton, and lesser hemp. Under the first method the lessee cultivated field crops during the first year, and sowed tree seeds along with the crops during the second year, carrying out two weedings during the rainy season; one line of tree seeds was sown alternately with three lines of field crops, and, the lines being about 1 ft. apart, the lines of tree species were about 4 ft. apart. Under the second method the tree seeds were sown in the first year of the lease in broad strips of four lines each 1 ft. apart, alternating with strips of field crops 8 ft. broad; the lessee cultivated field crops between the strips of tree seedlings for a second year and also weeded and sowed up blanks in the latter.

The first method had been tried only for a short time, but the results of the second method were promising, teak plants having attained a maximum girth and height of 6½ in. and 15 ft. respectively in 3½ years. In departmental sowings carried out on this principle the cost of formation during the first 3½ years, including collection of seed and weeding but not cost of supervision, amounted to Rs. 28-11-0 per acre, while the receipts from the produce of the field crops amounted to Rs. 32 per acre, leaving a profit of Rs. 3-5-0 per acre.

Broadcast sowing. Variable results have been attained with broadcast sowing. Where heavy weed-growth is not to be feared this method has been found to be decidedly successful as well as cheap, but where much weeding has to be carried out spacing in regular lines has usually been found preferable. Broadcast sowing, again, is suitable only for more or less level or gently sloping ground; on steep slopes broadcasted seed is liable to be washed away. In the Magwe district of Upper Burma, where the climate is dry, and heavy weed-growth is not so prevalent as in the moister districts, remarkable success has been attained by broadcast sowings of teak in *taungyas*. Here field crops are cultivated for two years, and this no doubt helps to eradicate weeds; the broadcasting of teak seed in the second year has resulted in well-stocked crops of teak. Mr. F. A. Leete¹ has advocated the more general adoption of broadcast sowing in Burma, and mentions that he has tried it in Pyinmana with great success; in 1910 he formed plantations half in regularly spaced lines at Rs. 10 per acre and half broadcast at Rs. 2 per acre, and in January 1912 he found equally good results in both. He notes that on steep slopes dibbling in lines is preferable, since broadcasted seeds are liable to be washed away. Subsequent reports from Pyinmana, however, indicate that these broadcast sowings gave some trouble in weeding, and in 1916 they were not so uniformly stocked as in the case of sowings in regularly spaced lines.

In June 1908 broadcast sowing of teak along with paddy was carried out in unprotected forest near Hmyachaung in the Tharrawaddy district; the area was burnt in 1909, and at the end of May 1909 two sample plots showed 1,360 and 1,760 seedlings per acre. Very little weeding was found necessary, and the cost amounted to about Rs. 2 an acre. This method imitates nature

¹ Ind. Forester, xxxviii (1912), p. 374.

in the matter of restocking abandoned cultivation with crops of teak, and deserves further trial.

A successful experiment in broadcast sowing was carried out in 1896 near Pinmadi in the Mohnyin reserve of the Katha district, Upper Burma. A patch of teak forest was heavily girdled, and the area was burnt and sown broadcast with teak seed. In the following year blanks were recleared and sown, the cover was thinned out, and the area was extended to 7.7 acres. The plantation was thinned in 1906, and in 1910 was reported to be well stocked with straight poles.

Broadcasting on ploughed land is said to have given good results in some cases in the Satara district of Bombay.

Dibbling. Under the head of 'dibbling' may be comprised operations for introducing teak or increasing its proportion over a given area by placing seed in the ground, not over continuous cleared areas of some extent as in the case of ordinary sowing, but in scattered gaps or comparatively small clearings within the forest. The dibbling of teak seed in the forest has been carried out for many years in various parts of Burma, but there has been very little to show for all the time, labour, and money spent on the work. Evident causes of failure in many cases are the fact that the dabbings have been carried out under cover of a forest canopy, that the seed has been buried too deep, or that it has been put into the ground too late in the season. If there is to be a reasonable chance of success dibbling should be carried out in open gaps or clearings, while the seed should be put into the ground before the commencement of the early showers preceding the monsoon, and should be very lightly covered. Even so, the success of the work depends on subsequent regular weedings, and here the trouble and expense of establishing crops of teak on any scale by this method at once becomes apparent, for however carefully the patches of dibbled seed may be marked they are often difficult to find subsequently, and the time occupied in searching for and weeding each individual patch of seedlings, should germination prove successful, in the great majority of cases renders the expense of this work quite out of proportion to the results attained. Moreover, the seedlings resulting from dabbings in the forest seldom show the vigour and rapid growth of those raised in *taungya* plantations, where the working of the soil and its enrichment with ashes greatly stimulate growth, and in consequence seedlings raised in forest dabbings take longer to outgrow weeds and are therefore subject to suppression for a longer time. Again, those plants which survive the first few years in small gaps in the forest require constant attention subsequently, for unless the canopy is kept open, bamboo and other growth being cleared, these plants must inevitably become suppressed.

In a moist climate like that of Burma, dabbings of this kind cannot be justified except for the purpose of increasing the quantity of reproduction over definite areas where concentrated regeneration is in progress, and where the intention is to remove the overhead canopy within a comparatively short time; in such cases weedings would be carried out systematically over the whole area, and the time occupied in searching for and weeding isolated patches would be saved. Experiments in Pyinmana have shown that dabbings have succeeded better in forest annually burnt over than in fire-protected

forest. Again, in the Ataran forest division in 1909 teak seed was dibbled in an old clearing about one acre in extent, and half the area was allowed to burn over, while the remainder was protected from fire ; in the burnt half the result was fair, while in the protected half complete failure resulted. This indicates that fire may prove to be a useful aid to the dibbling of teak in the moist types of forest met with in Burma.

In the drier types of forest in Bombay dibblings followed by the subsequent loosening and mulching of the soil round the resulting seedlings for two or three years has proved fairly successful in places, though better results have been attained with transplants.

Tending of teak plantations. The three main classes of tending operations in a teak plantation are weeding, cleaning, and thinning. The distinction between weeding and cleaning is not always clear, and the application of the terms varies locally. As a rule the term 'weeding' is applied to the removal of weeds, often of a herbaceous or shrubby nature, during the earlier life of the plantation, and particularly during the first three or four years, while the term 'cleaning' denotes the removal of inferior tree species and bamboos which threaten to suppress the teak at a later stage. The term 'thinning' is used here in a purely silvicultural sense, irrespective of whether the operation is remunerative or not. Except in dry localities, where they may sometimes be dispensed with, weedings are essential to the establishment of the young crop. Their number, frequency, and intensity depend on the nature and luxuriance of the weed-growth, and this in turn depends largely on the rainfall, though other factors also operate, for instance the fertility of the soil ; thus weeding is usually of a heavier nature on the fertile soil which previously supported tropical evergreen forest than on less fertile ground. The procedure for many years in the plantations of the Tharrawaddy district of Burma, where the normal rainfall varies from about 60 to 80 in., has been to weed annually for four years, including the year of sowing, and thereafter to weed or clean every alternate year until the first thinnings, about the tenth year. Thereafter cleanings are carried out at intervals of five years. In some cases two weedings are necessary during the first year.

Weeding is always carried out in the rainy season, when weed-growth is most luxuriant. In Burma clean weeding is considered unnecessary, the aim throughout the course of weeding and cleaning being to keep the heads of the teak plants well free, but not to lay them bare. In the weeding of the year after sowing or planting duplicate stems are removed and badly shaped and damaged stems are cut back flush with the ground. In the cleanings inferior species and bamboos which threaten the teak are cut out, or it is often found sufficient and even desirable to cut them at some distance from the ground. During the weedings and cleanings all climbers are cut, and the boundaries of the plantations should be kept clear of encroachment by the surrounding jungle, if necessary by maintaining a completely clear line round the boundary. In the Nilambur plantations the lines are clean weeded during the first season, the soil being loosened and the weeds pulled out ; this is found to stimulate growth and keep down weeds to such an extent that subsequent weeding is of a light nature. As a rule there are three weedings in the first year, one or more in the second year, and none in the third year except in areas of the

third quality ; on good soils the average height of the teak crop after three years is 16 to 22 ft., and weeds are killed out.

In Java the *alang* grass (*Imperata arundinacea*, Burmese *thekkè*) is a great scourge in young plantations. In order to prevent its ingress and to avoid the expense of hoeing, *Leucaena glauca* is sown between the lines of teak ; this plant keeps the soil clean, and is ultimately killed out by the teak.

The frequency, intensity, and conduct of thinnings in teak plantations are matters on which opinions differ to some extent, and the conduct of thinnings must naturally vary in detail with local conditions. It is generally held that thinnings should commence early, that is, at an age of about 10–12 years, or even sooner, and should be carried out lightly but frequently up to an age of about 25 to 30 years, after which plantations should be thinned somewhat more heavily and at gradually increasing intervals of time. In fast-growing plantations it has been found advisable to thin at intervals of five years. In Burma thinnings are ordinarily carried out at intervals of ten years, but it is recognized that in the case of the younger plantations this interval is too long, and has been adopted for the time being only because of the paucity of trained staff. In Travancore, according to Bourdillon, thinnings commence in the seventh year, and are repeated in the ninth, twelfth, sixteenth, and twentieth years, and thereafter every fifth year.

The scheme of thinnings for the Nilambur plantations has been recently revised under Mr. R. Bourne's working plan. Generally speaking, in areas of qualities I and II, thinnings under this scheme will commence at an age of five years, and will be repeated at intervals of five years up to an age of fifteen years, and thereafter at intervals of ten years up to an age of forty-five years, after which no further thinnings will be carried out ; in areas of quality III thinnings will commence at an age of ten years, and will be repeated at intervals of five years up to an age of twenty-five years, and thereafter at intervals of ten years up to an age of forty-five years, after which no further thinnings will be carried out. The first thinning in each case is purely mechanical, every alternate plant being removed from the lines in such a way as to leave the remaining plants evenly spaced in squares, but each occupying double the area it occupied previously. The last thinning is in the nature of an increment felling ; the number of stems left to form the final crop must vary with the state of the crop, but the number per acre is roughly 35 on soils of quality I, 45–50 on soils of quality II, and 65–70 on soils of quality III. The yield table given below (p. 763) under 'statistical' shows the average number of stems per acre left after thinning, and the intermediate yields at different ages in the Nilambur plantations.

Mixtures in plantations. The question of mixtures in teak plantations is one which deserves further study. Teak is not a good soil-improver, and it would often be advantageous silviculturally, where a natural underwood of bamboos and woody species does not make its appearance, to introduce an underwood artificially, choosing where possible a useful species whose cultivation would be remunerative. Various species have been tried in mixture with teak, but where the companion species has been introduced along with it, one of the two has almost invariably failed through being outgrown and suppressed by the other. Where insect damage is to be guarded against,

therefore, it would be preferable to create small blocks of pure teak, alternating with similar blocks of other species. Where the object is to introduce a soil-protection wood or a useful accessory species it would be preferable to employ a shade-bearer and to introduce it beneath the teak, thinning the latter out more heavily than would otherwise be the case. In Coorg the system, tried in recent years, of sowing teak, *Dalbergia latifolia*, and *Pterocarpus Marsupium* in alternate lines has not proved altogether satisfactory, since the slower initial rate of growth of *Dalbergia* and *Pterocarpus* necessitates tending for some time after the teak is established, while later these two species outstrip the teak in height-growth and may give trouble; it has therefore been proposed to form pure plantations of these three species in alternate blocks not exceeding 50 acres in extent. *Artocarpus hirsuta* has been introduced below teak with considerable success in Travancore, and there are other useful species which might be tried in this way, such as *Hopea parviflora* or *Xylia xylocarpa* on the west coast and *Xylia dolabriformis* in Burma. In Java *Schleichera trijuga* is looked upon as a very useful soil-protective species under teak.

In Burma mixed plantations of teak and cutch (*Acacia Catechu*) have been formed on a fairly extensive scale; these species do not mix well, but tend to separate out into pure groups, the teak claiming the ground suitable for it, and the cutch occupying the less favourable ground. When such plantations are made nowadays it is usual, therefore, to mix the two species by groups, sowing the teak on the better-drained and more fertile ground and the cutch on the less well-drained or poorer ground. Other species which have been tried in mixture with teak in Burma are *Xylia dolabriformis* and *Pterocarpus macrocarpus*, both on a very small scale, and without success; mahogany, which, as was found also at Nilambur, proved unsuitable for mixture with teak; *Cassia siameu*, which was sown in alternate lines with teak, soon overtopped the latter, and had to be cut out; *Millettia Brandisiana*, result not recorded; and mango, which in course of time disappeared for some reason not recorded. In the Katha district of Upper Burma recent experiments have been carried out in interplanting teak with *Cassia Fistula*, *Xylia dolabriformis*, *Dysoxylum binectariferum*, *Gmelina arborea*, *Bombax insigne*, *Cedrela Toona*, and *Lagerstroemia Flos-Reginae*. Of these the last two, and particularly *Lagerstroemia*, show promise. *Gmelina arborea* was found to grow too fast and to branch too freely for mixture with teak in alternate lines.

Certain mixtures have been tried in the Andamans. Between 1883 and 1889 teak and padauk (*Pterocarpus dalbergioides*) were sown 4 ft. apart in alternate lines 9 ft. apart, but the teak soon outstripped and suppressed the padauk. In 1913 teak was sown 3 ft. apart in lines 24 ft. apart, padauk and *Albizia Lebbek* being sown broadcast between the lines of teak. In the same year teak was planted with a spacing of 12 ft. by 6 ft. with casuarina between, but the latter failed.

SILVICULTURAL TREATMENT. The tending of teak in artificial crops has already been dealt with; it will be convenient here to deal with the management and silvicultural treatment of teak forests under separate heads: (1) coppice systems, (2) high forest systems of the selection type, (3) high forest systems with concentrated regeneration, (4) teak in relation to bamboos.

1. *Coppice systems.* In the drier parts of the Indian Peninsula, where

teak does not reach any great size, the system of coppice-with-standards is largely followed. This is particularly the case in the Bombay Presidency, where a large proportion of the teak-bearing forests are worked under this system. Coppice-with-standards is also the system followed in parts of Madras and the Central Provinces.

In Bombay the coppice rotation hitherto most commonly adopted is one of 40 years, though the rotations actually vary from 30 to 60 years, and recently the long rotation of 80 years has been adopted in two of the Kanara working plans. The rotation for standards, in the few cases where it has been fixed, is one of 60 or 80 years, being twice the rotation for coppice. The number of standards to be left, according to working plans prescriptions, varies from 15 to 45 per acre. In the Golihalli-Godoli teak forests of Belgaum the system of simple coppice is in force, standards being reserved only where the growth is exceptionally good. The opinion is gaining ground in Bombay that some of the forests hitherto worked under coppice-with-standards, particularly the Thana forests, could be worked more profitably and successfully under simple coppice with a long rotation, namely 80 years, no standards being reserved: this does not, however, apply to very steep or poorly stocked hill-slopes. This opinion has been formed on the ground that clear-fellings are more suitable for teak than any form of two-storied forest, that teak coppices to an advanced age, and that if cultural operations are properly carried out there is no necessity to retain seed-bearers. In areas worked as coppice-with-standards, again, the opinion seems to be now prevailing that 15 to 20 standards per acre, as a maximum, are ample if the coppice is not to suffer from domination.

In the Central Provinces a system known as partial coppice or coppice selection is practised, for the most part in remote coupes where there is only a limited demand. Its main object is to replace deteriorating and badly shaped stems by straight coppice shoots, and with this end in view such stems are coppiced flush with the ground, even where the coppicing of the whole coupe is impracticable. At the same time, standards are reserved as in the ordinary coppice-with-standards system. The main felling is followed by the systematic cutting back of badly shaped or otherwise undesirable stems. These cutting back operations for the improvement of the young crop are found to be most useful in the forests of the Central Provinces, where the teak is so often misshapen, owing to past maltreatment.

Although teak coppices extremely well, seedling reproduction in the Central Provinces is often very poor, and it is by no means certain that repeated coppicing can be carried out indefinitely; this has given rise to some apprehension as to the future, and has indicated the desirability of introducing seedling reproduction artificially in coppice coupes where natural seedling reproduction is wanting.

Mr. A. G. Edie¹ has recorded the results of an experiment carried out in the pole areas of North Kanara to find out the effect of thinning out the weaker shoots of a stool on the subsequent growth of the remaining and stronger shoots. In four plots altogether 131 stools were thinned and 131 left unthinned. The resulting shoots were measured the year of thinning and subsequently at an interval of two to four years, but in the case of the unthinned stools only

¹ Ind. Forester, xlii (1916), p. 157.

the dominant shoots were measured, corresponding to those left in the case of the thinned stools. The following statement shows the results of the measurements :

Tectona grandis : measurements in thinned and unthinned coppice, North Kanara.

Plot No.	Age at time of thinning.	Interval after which remeasurement was made.	Percentage of shoots thinned out.	Increment per annum.			
				Height.		Girth.	
	years.	years.	per cent.	Thinned.	Unthinned.	Thinned.	Unthinned.
				ft.	ft.	in.	in.
1	3	3	64	2.11	2.19	1.13	1.05
2	7	2	67	1.05	0.98	0.82	0.62
3	9	4	..	..	..	0.82	0.77
4	15	4	..	..	..	0.45	0.35

These figures show a girth increment in favour of the shoots of the thinned coppice, though the effect of the thinning is hardly so great as might be expected. Mr. Edie remarks, regarding this experiment, that thinnings in coppice are probably advisable, but that these should not be undertaken until the coppice is at least ten years old, partly in order to preserve the cover and partly because if shoots are thinned out in young coppice new shoots take their place.

2. *High forest systems of the selection type.* The treatment under high forest of vast areas in which teak, a strong light-demander, occurs scattered among numerous other species in constantly varying types of forest in which bamboos often play an important part, is by no means an easy problem, and the method of treatment hitherto applied almost universally to the extensive teak forests of Burma and to the better classes of forest on the west coast of India is in no way a solution of that problem. This method of treatment has been termed the selection system, but it is not the true selection system of Europe, since it does not provide for the attainment of normality or ensure a sufficiency of reproduction, nor does it even take the silvicultural requirements of the teak into consideration. Briefly stated, this method of treatment consists in working over a given tract of forest in a definite felling cycle and cutting out those teak trees which have reached a certain minimum girth, with the proviso that where teak reproduction is absent, seed-bearers should be left ; in most cases the maximum number of trees to be removed in any year or period of years is fixed. This system was adopted in Burma in the early days of forest organization as being the only practicable method of utilizing, under some sort of control, the stock of mature teak over the extensive areas of forest to be dealt with. As a provisional method of treatment it was the only one to adopt under the circumstances. Yet with the exception of one or two recent innovations, which will be noted below, it has continued to be the system in force throughout Burma down to the present day, and it must continue to be practised over considerable areas for some time to come, since the introduction of more rational systems of management over the vast areas to be dealt with must take time.

It has never been denied that the cutting out of all mature teak trees from among their numerous associates will in time lead to a serious diminution of the principal species, and hence working plans have prescribed the removal of inferior species in the interests of immature teak of all ages. But in actual

practice it has been found quite impossible to carry out these improvement fellings, as they are termed, on anything like the scale necessary to keep up with the felling of teak trees, more especially since experience has shown that in the case of young teak still in danger of suppression from weeds and bamboos a single felling is insufficient, and cleanings require to be repeated, it may be several times, before the young teak are out of danger.

The note of alarm in respect of selection fellings in Burma was first sounded after the adverse effects of continued fire-protection on the establishment of teak reproduction came to be realized, and the conclusion was reached that the combination of continued fire-protection with selection fellings would ultimately lead to the extinction of teak over large areas of forest. The argument that the abandonment of fire-protection will bring about the desired result without any alteration in the method of treatment will not hold, for the constant cutting out of the teak, without the possibility of carrying out improvement fellings for the benefit of that species on anything like the scale necessary, is bound eventually to deplete the stock of teak. Again, if the reproduction and establishment of the teak crop is to receive special encouragement, some regard must be had for the requirements of the species in such matters as exposure of the soil to the sun for purposes of germination, clearance of overhead cover to afford abundance of light and to prevent mortality from drip, and repeated weeding and cleaning. Finally, in most of the forests in which teak has hitherto been worked under selection fellings, the proportion of that species might be largely increased without undue risk of insect or fungus attacks, and much fertile ground which is at present unproductive might be utilized profitably. These considerations, apart from other advantages to be secured from concentration of working, have within recent years led to a fairly general consensus of opinion in Burma that the selection fellings hitherto in vogue should be superseded, when and where circumstances will permit, by some system of concentrated regeneration whereby the proportion of teak will be not only ensured but increased.

A brief account of the method of selection fellings hitherto practised in teak forests may be of interest. In Burma it has long been the custom to girdle teak trees three years before felling them; this girdling, which consists of ringing them completely down to the heartwood near the base of the tree, is carried out primarily with the object of rendering the timber buoyant for floating purposes, but it also serves to season the timber before felling and extraction. Trees are selected for girdling, provided they have attained the prescribed minimum girth and are not required as seed-bearers, and are felled at least three years later. The exploitable girth most commonly adopted in Burma is 7 ft., or 6 ft. in dry types of forest, but in some cases it is fixed at $7\frac{1}{2}$ or 8 ft. The age corresponding to a girth of 7 ft. is with very few exceptions estimated to be from 150 to 180 years. The exploitable age is divided into a convenient number of periods, which actually vary from 20 to 40 years, but are for the most part 30 years in duration; the period is equivalent to the cycle during which fellings go completely round the whole area. The period is divided into sub-periods, which usually vary from four to eight years each, and corresponding sub-periodic blocks are laid out on the ground. The object of these blocks is to afford elasticity of working, in that girdling is not

confined each year to a definite annual coupe, but may be carried out in the prescribed sub-periodic block at any time during the sub-period.

The better types of teak forest in Bombay and Madras are worked as a rule under selection fellings of a similar kind. In North Kanara and Thana the exploitable size fixed is a diameter of $18\frac{1}{2}$ or 24 in., or a girth of 6 or $6\frac{1}{2}$ ft. The rotation, where calculated, varies from 120 to 160 years, and the felling cycles adopted vary from 15 to 30 years. The yield is usually fixed by number of trees, and in some parts of North Kanara girdling is carried out two or three years before felling.

In the Allapilli forest of South Chanda in the Central Provinces teak is worked under selection fellings with an exploitable girth of 6 ft., corresponding to an estimated mean age of 175 years.

Improvement fellings of the selection type are carried out in parts of the Central Provinces and Madras, and in various parts of Bombay, particularly in Khandesh. These fellings have for their object the removal of over-mature, badly shaped, and otherwise undesirable stems, and are carried out under a definite felling cycle, which ordinarily varies from 10 to 30 years, but is in two cases as long as 45 years. These improvement fellings are often followed by cutting back operations in the young crop, with the object of producing straight coppice-shoots.

It will be convenient to allude here to the tending operations, termed improvement fellings, which are carried out as far as staff and labour permit in the teak forests of Burma. These fellings are of two separate classes : (1) 'O' improvement fellings, made in the interests of the old crop, and (2) 'Y' improvement fellings, made in the interests of the young crop. The 'O' fellings are in the nature of a thinning in a mixed crop, and apply to trees which have passed out of the pole stage ; they are carried out as soon as possible after the extraction following the main fellings, and the intention is to repeat them at intervals of 15 years, though this interval is recognized to be too long in many cases. The object of these fellings is to free promising stems of teak and other valuable species by the removal of undesirable stems which are interfering with their development, care being taken, however, not to open the canopy to such an extent as to cause an invasion of weeds.

The 'Y' improvement fellings have for their object the establishment of such natural reproduction of teak and other valuable species as may be found on the ground. They are in the nature of weedings and cleanings, and consist of the removal of weeds, bamboos, and inferior tree species which are interfering with the development of seedlings, saplings, and poles. The cutting back of badly shaped, damaged, or suppressed saplings is carried out at the same time ; it has been found that badly suppressed saplings, if freed, do not as a rule recover their vigour, whereas if cut back they may send up strong new shoots. Where necessary, undesirable trees in the overhead canopy may be removed, provided that the canopy should not be opened to the extent of inducing heavy weed-growth which would suppress existing teak seedlings and saplings. These weedings and cleanings are carried out as soon as possible after the extraction following the main fellings, and are repeated as often as necessary and until the young crop is safe from suppression. As these operations are of an intensive nature they are confined to areas where there is

sufficient natural reproduction present to warrant their execution, and to areas from which extraction is easy. Within the area operated over, places containing no teak, but which are suitable for its growth, are regenerated artificially by the *taungya* system. These cultural operations, combined with artificial reproduction within the areas operated over, are interesting as showing an attempt to regenerate definite areas, and may be regarded as a transition stage towards the adoption of a regular system of concentrated regeneration tending towards the creation of even-aged crops.

These 'Y' improvement fellings have now been in operation in Burma for some years, and the experience gained so far indicates that they can rarely, if ever, justify themselves financially if they are carried out in forest under continuous fire-protection, and unless they are considered as a means towards the complete regeneration of definite areas with the aid of fire and in conjunction with the complete removal of overhead cover in the manner described below; even so the *taungya* system of regeneration has proved to be cheaper and more efficient. It has been found that 'Y' improvement fellings in fire-protected forest may be the means of saving from suppression, at considerable cost, saplings which are already established; they do not result in the appearance of new seedlings. In Tharrawaddy 'Y' improvement fellings repeated for four or five years have been found to cost Rs. 5 to Rs. 10 per acre for weeding and cleaning only, without the clearing of overhead cover, which is necessary for the proper development of the young growth, and in certain cases they have cost as much as Rs. 21 to Rs. 37 per acre when repeated for five years, with results quite incommensurate with the high cost and far less successful than would have been attained at a lower cost by the aid of *taungya* plantations.

3. *High forest systems with concentrated regeneration. Dutch East Indies.* The method of treatment of the teak forests in the Dutch East Indies has been described in a note by Mr. R. C. Milward.¹ The teak grows remarkably pure on the chalky soil on which it is commonly found, and efforts are made to encourage a mixture of other species, of which *Schleichera trijuga* is considered the most suitable, as it stands shade and keeps the soil in good condition. The present method of treatment is by clear-felling in plots of between 25 and 50 acres, followed by natural reproduction by seed or coppice, which is supplemented by artificial reproduction. The rotation arrived at is 100 years on good soils and 80 years on poor soils, the average diameter attained on the former being 24 to 32 in. The trees are girdled two years before felling. Sometimes the coupe is burnt over before felling, in order to assist the germination of the teak seed on the ground. Burning is in any case carried out after extraction is completed, the refuse being piled up against the old stumps to prevent the growth of coppice-shoots, which are not desired from these stumps. All the smaller stumps are then coppiced. Only one good coppice-shoot is left on each stool, the others being bent or half broken down a year or so after coppicing, in order to cover the ground. The growth of grass which tends to spring up on these large clear-felled areas is looked on as a disadvantage, and hence, although this system is very successful and comparatively easy, the Dutch foresters are on the look-out for some system which will prevent the

¹ Note on the Forests of Java and Madoera of the Dutch East Indies, 1915.

invasion of grass, such as natural reproduction in groups. *Leucaena glauca* is sown with the view of keeping down a heavy growth of grass.

Mohnyin and Bilumyo forests. The Mohnyin and Bilumyo forests in the Katha district of Upper Burma have already been described. They are situated near each other, on fairly level ground, and have an aggregate area of 27,489 acres. Teak occupies less than one-third of the area, but where it occurs it constitutes a greater proportion of the stock than is usual in the teak forests of Burma, becoming almost pure in places. The absence of bamboos over most of the area further increases the dissimilarity between these forests and the usual types of teak forest in Burma. The teak trees attain very large dimensions, and large trees are much in excess. A feature of these forests, which for some time caused uneasiness, is the almost entire absence of natural reproduction of teak. With the view of devising means of inducing reproduction, experiments were commenced by the late Mr. J. Messer about 1898 and continued for some years; they were subsequently carried on in turn by Messrs. McHarg and Blanford. These experiments demonstrated the fact that abundant natural reproduction, from teak seed lying dormant in the ground, could be induced by opening the canopy and by completely clearing and preferably burning the undergrowth. They showed, however, that the seedlings were rapidly killed off during the rainy season by the drip from overhead trees and by the weeds which sprang up. This indicated the procedure to adopt, namely, to remove all overhead cover possible, to cut and burn the undergrowth, and to weed and clean the young teak crop for two or three years. Figs. 287, 288, and 289 show the profusion with which natural reproduction of teak is capable of establishing itself under this treatment in areas in which it is entirely absent where these measures are not taken.

A working plan based on the results of these experiments was prepared by Mr. Blanford, and came into force in 1910-11, the fellings being prescribed for 20 years. The rotation adopted is 180 years, corresponding to an average girth of 8 ft., and is divided into nine regeneration periods of 20 years each, the periodic blocks being so allotted as to contain as far as possible an equal stock of teak. The working plan prescribed that periodic block I, to be regenerated first, should be divided into four 5-year coupes or compartments, corresponding to 5-year sub-periods, regeneration fellings being carried out by felling over the whole compartment in the first year of the sub-period, or failing this by the second year, all teak except promising compact groups of young trees. This prescription has subsequently been modified to allow for annual instead of 5-yearly coupes, in order to ensure complete extraction in one year over a definite area. The working plan prescribed the retention of exceptionally well-shaped clean-boled teak below 6 ft. in girth, even if isolated, but this has been found to be unsatisfactory, and is not acted on. The aim is to effect as complete a clearing as possible in order to prevent seedlings being killed by drip from overhead trees. All felled material which can be disposed of is at once extracted, after which the whole area is thoroughly burnt, all unburnt material being cut up, piled, and reburnt; if complete burning is not effected the first year, burning has to be repeated the second year. The working plan prescribed burning for two years prior to girdling, but this has proved to be a mistake, since it induces the germination of numerous



FIG. 287. Natural reproduction of teak induced by clearing overhead canopy, cutting and burning undergrowth, and weeding young plants, Mohnym, Upper Burma: plants of 2 rains' growth.



FIG. 288. Natural reproduction of teak induced by clearing overhead canopy, cutting and burning undergrowth, and weeding young plants, Mohnyin, Upper Burma: plants of 3 rains' growth.



FIG. 289 Natural reproduction of teak induced by clearing overhead canopy and undergrowth Mohnyin, Upper Burma area not burnt but weeded regularly plants of 4 rains' growth



FIG. 290 Regeneration fellings in Mohnyin forest, Katha, Upper Burma a regenerated area after the second rainy season with teak seedlings plentiful girdled trees not yet removed



FIG. 291 Natural reproduction of teak 1 year old in upper mixed forest, induced by clearing

teak seedlings which die owing to want of light and the presence of weeds, while the supply of seed lying dormant in the ground is reduced in quantity. The seedlings, which spring up in abundance as a result of the clearing and burning, are weeded from the commencement, and weeding requires to be continued for two or three years, or until the young plants are safe, after which periodical cleanings are necessary. As many as three weedings may be required during the first rains. It was hoped that annual burning of the young crop might serve to dispense with these expensive cleanings, but an experiment to this effect resulted in failure. Fig. 290 shows a regenerated area after the second rainy season, before the removal of the girdled trees. All blanks are planted up during the first rainy season with natural teak seedlings spaced 6 ft. by 6 ft. It is not safe to postpone this work for a single year, owing to the profusion with which grass springs up on cleared areas. Three years after girdling the girdled teak trees are felled and extracted. This does great damage to the young crop, and injured stems require to be cut back. It has, therefore, been decided experimentally to girdle the teak three years before the regeneration fellings, and to fell and extract it immediately before burning.

In periodic blocks II to IX, selection girdlings are prescribed which will pass completely over the area in the 20 years' period ; no tree under 10 ft. in girth will ordinarily be girdled unless it is obviously deteriorating.

Although the success of this system has been amply demonstrated, further experiments are still in progress with the view of reducing the cost of regeneration and of introducing mixtures of other species in order to avoid raising pure crops of teak. An interesting account of these operations has been written by Mr. H. R. Blanford.¹ The results of a recent experiment in regeneration under the *taungya* system bid fair to modify completely the operations prescribed in the working plan. It has been found that natural reproduction of teak, with an admixture of other species, springs up in abundance on areas cleared for temporary cultivation, and where reproduction is wanting the blanks can be easily filled up with transplanted natural seedlings. Regeneration under the *taungya* method very considerably reduces the cost ; on a Kachin *taungya* of 22 acres a complete and vigorous young crop has been established and brought through the first season at the low cost of Rs. 2 per acre. Under the prescriptions of the working plan as subsequently modified, the cost of regeneration from 1910-11 to 1917-18 has amounted to Rs. 40 per acre, which is prohibitive, although culturally the work has been successful ; this may be compared with the cost of a very successful *taungya* plantation formed in 1910-11, which amounted during the same period to about Rs. 19 per acre.

Burma teak forests in general. The great majority of the teak forests of Burma are characterized by the presence of an under-story of bamboos which greatly affects the treatment. The question of introducing some system of concentrated regeneration in these forests was considered at a conference held in Burma in 1910. The general scheme of management tentatively approved by the conference provided for the division of the rotation into periods. Periodic block I was to be treated under regeneration fellings with intensive weedings and cleanings, while the other periodic blocks were to be worked by selection

¹ Ind. Forester, xliii (1917), p. 339.

fellings. It was decided that regeneration fellings should consist of one main felling followed by subsidiary improvement fellings carried out where necessary at intervals of five years. The main fellings would consist of the girdling of mature teak trees, with a minimum girth of 7 ft. in moist and 6 ft. in dry forest, while other species would be completely cleared over young teak. The girdling of undersized teak was not contemplated except where necessary, in order to free promising groups of young trees and advance growth. Plantations and cultural operations, that is, repeated weedings and cleanings, and as far as possible also bamboo extraction and road-making, in order to encourage the utilization of species other than teak, would be concentrated in this block. The use of fire to stimulate natural reproduction was also contemplated. In the other blocks it was proposed to carry out selection fellings of teak and other saleable species. A system on these lines aims at increasing the proportion of teak and other valuable species, but not at creating even-aged crops of teak, though it tends towards the ultimate establishment of even-aged crops; at present such crops would be produced only where plantations are formed.

Since 1910 a great deal of useful experimental work in the natural regeneration of teak forests in Burma has been carried out, and as a result the opinion is gaining ground that the most satisfactory way in which to treat the natural teak forests of Burma wherever conditions permit is to produce even-aged young crops, though not necessarily pure crops of teak of large extent. For this purpose complete clearance of the overhead canopy is necessary, and it is accordingly considered advisable as far as possible to confine this intensive form of regeneration to localities where at least the more valuable species of trees other than teak are marketable. For this reason the allotment and sequence of regeneration areas should be made in conjunction with schemes of roads or other export works. It has further been found to be of great advantage to reduce to a minimum the time taken to regenerate a given area completely, that is, the time from the first regeneration felling to the complete establishment of the young crop. For the production of even-aged crops it will be necessary to sacrifice immature teak trees, but the ultimate gain, in the production of a largely increased future stock of teak, is held to justify this sacrifice. Theoretically the areas to be placed in periodic block I, to be regenerated first, should be those containing most mature trees and least reproduction. But actually it is considered advisable to maintain a supply of mature teak to provide for the outturn some years hence, owing to the depletion of many of the important teak tracts by heavy fellings in the past and to the diminution of the number of teak trees outside reserved forests with the extension of cultivation. This being so, it is held to be preferable to regenerate first (1) areas which are capable of producing teak of good quality, but in which teak is scarce or absent, and (2) areas containing much established reproduction, including plantations. Allotment to other periods is as a rule unnecessary, except that periodic block II should be allotted tentatively and the exploitable size in it should be placed higher than in the other blocks, in order to retain as many teak seed-bearers as possible, and to maintain the future yield.

As regards the method to be employed for regenerating a given area, the

method of *taungya* plantations, from the point of view of efficiency and economy, has proved far superior to any other method yet devised, however successful. These plantations should, if properly carried out, seldom cost more than Rs. 20 per acre to establish completely, and where no rewards are given for raising the young crop of teak they should cost a good deal less. Experimental work in obtaining natural reproduction by felling, burning, and weeding has shown that crops far less fully stocked cannot be raised except at a considerably higher cost than in the case of *taungya* plantations. For the systematic formation and upkeep of these plantations on a large scale the establishment of forest villages will in most cases be necessary. This will ensure a permanent supply of forest labour for work other than that connected with plantations, while in addition the food of the labour force will be produced on the ground.

Failing *taungya* plantations, experiments carried out in the upper mixed forests of the Pegu Yoma so far indicate the following to be the sequence of operations necessary to secure natural reproduction :

(1) The area should be fire-protected for two or three years before fellings are commenced, in order to ensure a plentiful crop of teak seed on the ground.

(2) All trees should be felled or girdled except those required as seed-bearers and compact groups of poles of teak and other valuable species which are not too old to form part of the future crop, but all solitary poles, including teak, should be cut, together with all bamboos and shrubby undergrowth ; this should be completed by the hot season.

(3) The whole area should be thoroughly burnt in the hot season, the fiercer the fire the better being the results ; it may be necessary to burn again for another year or two before a sufficient crop of young teak is secured.

(4) This felling and burning is usually followed by a good crop of young teak and other species where seed-bearers are plentiful and where the fire has been intense ; all trees standing on the area should be felled and removed during the cold season following the appearance of the young crop, or if teak is not to be felled green it should then be girdled, extraction being carried out three years later.

(5) The young crop should be weeded, usually three times during the first rainy season, and subsequently as often as necessary until it is established.

(6) After the extraction of girdled teak, damaged young growth should be cut back.

(7) After the burning the area should be fire-protected as long as weeding is necessary ; thereafter experience should determine whether it is better to continue fire-protection or to burn early in the season.

Fig. 291 gives an idea of the success with which natural reproduction has been obtained on an experimental scale in the Saing Yane reserve of the North Toungoo division by clearing the overhead cover, felling bamboos, thoroughly burning, and weeding the resulting natural teak seedlings.

A system of concentrated regeneration fellings somewhat on the lines just indicated is being introduced throughout the whole of the hill forests of Tharrawaddy. For the present the rotation is to be fixed at 120 years, divided into six periodic blocks of twenty years each. In the blocks not under regeneration, subsidiary selection fellings, with thinnings, will be carried out under

a felling cycle of thirty years, areas likely to be placed in periodic block II being excluded from girdling during the first twenty years.

Teak forests of the Indian Peninsula. In the moister and better types of teak forest in the Indian Peninsula, which have hitherto been worked under fellings of the selection type, there is scope for the introduction of concentrated systems of regeneration such as those which are being introduced in Burma, though the details must vary with local conditions. In the drier types of forest a commencement has already been made in Bombay by the system of tending and mulching natural seedlings in newly felled coupes, combined with artificial reproduction. Experiments on similar lines in Berar have indicated the necessity for removing overhead cover to prevent drip from overhanging trees, and this is a step towards the creation of even-aged crops over definite areas.

The Nilambur teak plantations. These plantations have recently begun to reach maturity, and it has been decided to fix the rotation at 70 years, which under conditions prevailing hitherto produces average girths of 6 ft., 4 ft. 9 in., and 3 ft. 7 in. on soils of first, second, and third quality respectively; under the new scheme of thinnings introduced recently these girths should be exceeded in the second rotation. The manner in which the various soil qualities are intermingled on the ground precludes the adoption of different rotations for the different qualities. The system of management is that of clear-felling with artificial reproduction by replanting. It has been found that on areas where clear-felling followed by burning of refuse has been carried out, plentiful crops of natural seedlings, sometimes of great density, make their appearance. These crops, however, are patchy, owing to the fact that the seeds are washed together on certain parts of the area and may be scarce or absent on other parts. The natural crops would no doubt flourish if left and tended, but it has been found better to ignore them and to replant with regular spacing, as weeding and early thinning are much facilitated thereby. Hence only those natural seedlings are retained which are required to replace failures among the artificially raised plants, and which happen to be situated somewhere near the blanks to be filled; all other natural seedlings are treated as weeds and removed.

4. *Teak in relation to bamboos.* In Burma, as well as in parts of India, the treatment of teak is intimately connected with a study of the habits of the bamboos associated with it. Some remarks on the habits of bamboos in general will be found under *Bambuseae*. In Burma these bamboos are of many different species and vary much in character and habit, and the question of obtaining adequate teak reproduction, whether naturally or artificially, involves many problems which are not always easy of solution. It will be convenient to deal with the question separately from the point of view of bamboos which are not in flower and those which are flowering or have flowered.

As regards bamboos which are not in flower, it has been demonstrated on many occasions in Burma that natural reproduction of teak can usually be obtained by felling the bamboos, opening the canopy and clearing undergrowth for some distance round seed-bearers, thoroughly burning all the cut material, cutting back saplings which are injured by fire, weeding for two or three years the teak seedlings which appear on the ground, and subsequently keeping them clear of overhead bamboos and other growth. Where thorough burning is not carried out, failure is almost invariable. An interesting

experiment in the clearing of bamboo, carried out by Mr. A. Rodger in 1916 in the South Nawin reserve, Prome, may be noted. The forest consisted of dense *kyathaung* (*Bambusa polymorpha*) on a cold northerly aspect, with a few mature teak and pyinkado (*Xylia dolabriformis*). The bamboos, 37 clumps in all, were cut in January for a distance of about 20 yds. round a teak seed-bearer; the cut material was burned in the ordinary course, the area not being fire-protected, and part of the cleared area was hoed up. There was an advance growth of 22 suppressed teak plants already on the ground, and these were marked. Next year all these had disappeared under the influence of the sudden clearing, but in their place no fewer than 123 new teak and 565 pyinkado seedlings had appeared; there was nothing to show that these were more plentiful on the hoed ground than elsewhere. These seedlings only required regular weeding and freeing from overhead bamboo cover to establish a promising young crop. This experiment is interesting as showing that teak natural reproduction can be established in a type of bamboo forest which produces trees of large size and straight growth, but in which natural reproduction is often scarce or absent owing to the heavy shade of the bamboo. The death of the pre-existing teak plants is also of interest. This does not always occur in freeing teak seedlings and saplings from overhead bamboo cover, and the effect probably depends on the extent of the change of conditions suddenly brought about by the clearing, on the vigour of the plants freed, and on the severity of the fire. Possibly cutting back the saplings immediately before or immediately after the burning might assist in their survival.

The effect of opening and burning bamboo forest is illustrated by the following quotation, relating to the Tharrawaddy forest division, from the Burma Forest Report for 1916-17:

'In one plot of *kyathaung* (*Bambusa polymorpha*) forest which had been heavily worked over in 1915-16 by bamboo-cutters, who had left much trash behind them, an accidental fire occurred. Owing to the dry bamboo trash the fire was more than usually fierce. In the following December the Range Officer drew the Divisional Officer's attention to the number of new teak seedlings which he had observed and marked. So many had come up that it was hardly possible to believe that they had not been artificially sown, since the seed-bearers stood at some little distance. In another "Y" felling plot in the same compartment the same fire had caused some dry trees to fall and burn clear lanes through the young growth of *pyinkado* and bamboos. Several of these lanes contained a row of new teak seedlings which at first sight appeared to have been lined out by hand.'

As regards the tending of teak plants in bamboo forest, periodical cutting of the bamboo is necessary until they are free from danger of suppression, and this work is costly. An experiment carried out recently in Pyinmana showed that good results can be obtained by cutting the bamboo clumps about 5 ft. from the ground; they then develop side branches which keep down weeds. New culms which appear are cut off annually at the same height.

The importance of the flowering of the bamboo in connexion with the reproduction of teak lies in the fact that in the case of the more important species gregarious flowering takes place, usually at long intervals, over

considerable areas of forest, and after flowering the bamboos die; the dead culms then fall by degrees and, in burnt forests, become consumed by fire. The admission of light and heat caused by this opening of the bamboo cover stimulates the natural reproduction of teak provided fire is admitted. The influence of bamboo flowering on teak reproduction has at times been called in question, but it is now known from various recorded observations to be a fact that it has a very decided influence. I have myself observed its undoubted effects in the Pyinmana forests, following on a general flowering of *Cephalostachyum pergracile*. Mr. J. W. Oliver¹ has recorded the following statement: 'Where there are a sufficient number of parent seed trees an intense fire following the flowering and dying of bamboos generally gives rise to extensive reproduction of teak, without the aid of artificial sowings. Instances of this may be studied in the Setkala reserve in the Bhamo division and in some of the reserves on the right bank of the Shweli river in the Ruby Mines division; the Nanme reserve is, I think, the particular locality I have in mind.' In the same connexion the following passage may be quoted from the Report on Forest Administration for the northern circle, Upper Burma, 1907-8: 'Observations made during the year show that the flowering of the bamboo, *tinwa* (*Cephalostachyum pergracile*), which has been advancing in a wave southwards over Upper Burma during the last four or five years, has had markedly beneficial results on teak reproduction.' In the following year the Report says: 'Observations of the year confirm the view expressed in the last Annual Report that the reproduction of teak in areas in which bamboos have flowered and the debris been burnt, or allowed to burn, leaves little to be desired. On the other hand, where bamboos have flowered and the area has not been allowed to burn for fear of damage to contractors' logs and naturally dead and windfall timber, a tangled mass of vegetation consisting of creepers and weeds and old bamboo stems encumbers the ground, and not only prevents any fresh germination, but also hopelessly smothers any seedlings which might previously have existed.'

It is evident that in the types of forest met with in Burma the admission of fire is necessary in bamboo-flowered areas where natural reproduction of teak is desired. For how long, if at all, burning is necessary after the year of seeding of the bamboo will depend on local conditions and on the extent to which weeding and cleaning can be carried out. Young bamboo growth is far less adverse to the establishment of teak reproduction than certain other weeds—for instance, *Eupatorium odoratum*, *Alpinia*, *Strobilanthes*, gingers, &c.—but if it is fire-protected, young bamboos form very dense masses, which if cleaning cannot be carried out may do much harm by suppression.

Mr. C. B. Smales² notes that in areas in the Thayetmyo and Prome districts, where *Dendrocalamus strictus* and *Bambusa Tulda* had recently flowered and where fire-protection had been abandoned, the bamboos established themselves in dense masses even where late burning had been carried out in order to destroy the seed. Here teak seedlings contemporaneous with young bamboo were not found surviving except on the edges of the flowered areas where the fire had not been so intense. The only successful teak saplings

¹ Ind. Forester, xxxiii (1907), p. 242.

² Notes on a Tour in Forests on the West Slopes of the Pegu Yoma, 1917.

found were those which had already been on the ground prior to the flowering. This indicates that advance growth must play a prominent part in operations for securing natural reproduction of teak at the time of flowering of the bamboo. Mr. Smales, therefore, advocates stimulating advance growth as much as possible, in view of an expected general flowering of *Bambusa polymorpha*, by cutting gaps in the bamboo cover round teak seed-bearers and elsewhere, and sowing teak seed in these gaps.

Fig. 292 shows a group of promising advance growth of teak in an area of flowered *Cephalostachyum pergracile*. The dead culms have fallen or been broken down and undergrowth has been cut. As the young teak is weak and crooked the intention is to burn the area and cut back the teak.

In Burma great stress is laid on the necessity for carrying out extensive operations for effecting the reproduction of teak when *Bambusa polymorpha* flowers gregariously, as it is expected to do before very long. This bamboo is certainly of paramount importance, but there are other important bamboos, notably *Cephalostachyum pergracile*, which have frequently flowered gregariously in different localities, although the flowering has too often been allowed to pass by without any special operations being carried out in order to take advantage of it and to gain experience of how to proceed in the event of a general flowering of *Bambusa polymorpha*.

Based on such experience as has been gained in the treatment of teak in bamboo-flowered areas, certain measures were prescribed in 1914 in anticipation of a general flowering of bamboo, and particularly of *Bambusa polymorpha*. These measures comprise the following: (1) collection and storage of large quantities of teak seed annually, utilizing it for plantations and other operations before it deteriorates, in the event of the flowering not taking place; (2) previous selection of suitable bamboo areas in which to conduct operations, (3) careful protection of flowered bamboo areas from fire until the end of the hot season, followed by burning before the rains commence, in order to destroy as much bamboo seed as possible, even if dibbling of teak seed cannot be carried out; (4) removal of low overhead cover as far as possible prior to burning, and girdling of all large trees other than teak at the same time as or as soon as possible after burning; (5) dibbling of teak seed immediately after burning, roughly 6 ft. by 6 ft., two seeds in each hole not more than 1 in. deep; dibbling to be confined as far as possible to well-drained and accessible ridges and spurs, and to a distance of two chains on either side of them, broad, flat, badly drained ridges being avoided; broadcast sowing to be tried only on flat ridges and gentle slopes; (6) in the first and subsequent years after dibbling, burning to be carried out, if required, early in the season, in order to destroy fallen culms; weeding to be carried out, twice in each of the first two years and once in the third year. The total cost of these weedings is estimated at Rs. 15 per acre.

These prescriptions appear to be suitable so far as they go except in one particular, in which they are open to criticism, that is in the proposal to confine dibblings to a distance of two chains on either side of ridges and spurs, By so doing the mistake made in respect of so many of the Burma plantations, namely in scattering operations and thus greatly increasing the cost of upkeep, will be repeated. Again, the richest areas, where teak reaches its finest

development, are not the tops of the ridges but the well-drained fertile lower slopes, and it is here in particular that the stock of teak should be increased. The prescription might well be altered to include the sowing up of compact and not straggling or scattered areas, comprising not only the ridges and spurs but also the lower slopes and well-drained valleys. The areas operated over will be nothing more or less than plantations; they will in a short space of time be indistinguishable from *taungya* plantations, and will require to be tended in exactly the same manner. Indeed the regeneration of bamboo-flowered areas by the system of *taungya* plantations pure and simple will probably prove more efficient and less costly than the measures described.

Some examples of teak sowings in flowered bamboo areas in Burma may be quoted. In these sowings it has always been found that their success decreases and their cost increases with each year's delay after the year of seeding of the bamboo. This is due mainly to the extra cost and difficulty of weeding and cleaning with every year's start given to the young bamboo, for weeding and cleaning in young bamboo areas may be a very heavy item.

In the Kônbinlin reserve of the Tharrawaddy division, where *Cephalostachyum pergracile* flowered gregariously in 1887, operations for increasing the quantity of teak were continued for seven years after the flowering of the bamboo. These operations consisted in girdling or felling and burning the tree-growth, cutting and burning the dead bamboo and afterwards the young bamboo growth, and dibbling teak seed as in a *taungya* plantation. The total area operated over exceeded 300 acres. This work showed clearly the advantage of the earlier over the later plantations, both in cost and in degree of success. In the case of these sowings the weeding was found to be a much heavier item than in the case of *taungya* plantations, and the average cost per acre during the first ten years worked out at Rs. 33-6-0 for the flowered bamboo sowings as against Rs. 20 for *taungya* plantations in the same locality; thereafter the cost in either case has been much the same. A considerable area of these flowered bamboo sowings has proved to be highly successful culturally, resembling a well-stocked plantation with a dense underwood of bamboo, which gives the teak a healthy and natural appearance.

Another successful series of flowered bamboo plantations has been formed to the east of Nyanlè, in the Taungnyo reserve of the Zigôn division. *Dendrocalamus strictus* flowered in 1878-9. Operations were commenced in 1881, that is, two years later than was advisable, and further areas were taken in hand in 1882 and 1883, the total area operated over in the three years being about 750 acres. The work consisted in felling all trees and bamboos, thoroughly burning, and sowing teak seed as in a *taungya* plantation. This was followed by weeding for three successive years, with another weeding in the seventh year in the case of the 1881 sowings and the fifth year in the case of the later sowings. The cost per acre of the three years' sowings up to the fourth year of weeding was as follows:

- (1) 1881 sowings: first 3 years, Rs. 8-14-0; weeding of 7th year, Rs. 0-11-3: Total, Rs. 9-9-3 per acre.
- (2) 1882 sowings: first 3 years, Rs. 15-9-0; weeding of 5th year, Rs. 2-6-0: Total, Rs. 17-15-0 per acre.
- (3) 1883 sowings: first 3 years, Rs. 17-3-0; weeding of 5th year, Rs. 1-8-2: Total, Rs. 18-11-2 per acre.

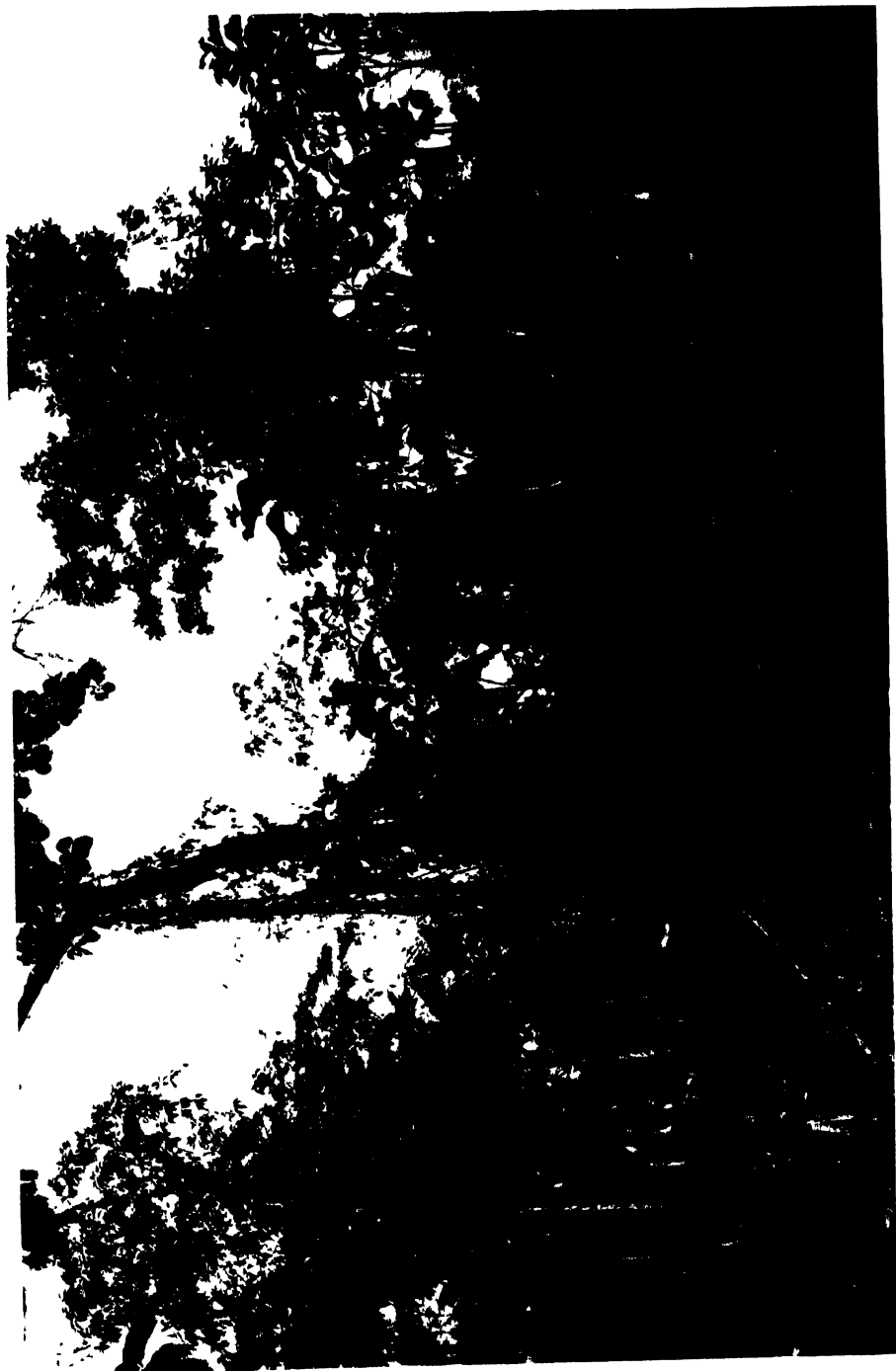


FIG 292 Natural reproduction of teak in area where bamboo (*Cephalostachyum pergracile*) has flowered Myit-kyina, Upper Burma undergrowth cut, but area not yet burnt, and young teak generally weak and crooked, burning and cutting back of teak will be carried out



FIG 293 Sowing of teak and cutch (*Acacia Catechu*) in flowered bamboo area,
Bwet forest, Promé Burma — cutch tree on left

These sowings have proved a great success, and are now represented by large areas of well-grown teak poles.

In the same neighbourhood, and to the north of Nyanlè, where *Dendrocalamus strictus* flowered in 1893-4, teak seed was dibbled among the unburnt bamboos in June. This proved a failure owing to insufficient felling and burning.

These examples will serve to show that very successful plantations can be established in flowered bamboo areas, provided operations are commenced as soon after the seeding as possible, that all overhead cover is cleared and thoroughly burnt, and that regular weeding is carried out in the young crop. Among other successful works of this kind may be mentioned the sowings in the Bwet reserve, Prome, following on a flowering of *Dendrocalamus strictus* in 1876. These would probably have been even more successful had not a good many large trees remained unfelled on the area. Recent flowered bamboo sowings in Prome have been supplemented by the transplanting of teak seedlings; of these natural forest seedlings have been found more successful than nursery seedlings, and of the former plants one year old or more have proved superior to young seedlings of the first rains. A successful example of the use of transplants in stocking a flowered bamboo area may be quoted from Katha, Upper Burma:¹ 'In the Katha division *tin* bamboo (*Cephalostachyum pergracile*) flowered in 1905 in the northern part of the division. The area was burnt in the hot weather, which stimulated the growth of coppice-shoots from teak stems burnt back. As natural teak seedlings did not spring up, nurseries were made and seedlings planted out in the rains of 1906 and 1907. The area was cleaned from time to time, and there is now (1914) a fine crop of young teak on the ground which only needs an occasional cleaning. The area treated was about 500 acres. The cost of the operation was about Rs. 10 per acre.'

Fig. 293 shows a young crop of teak mixed with cutch raised by sowing in a flowered bamboo area in the Bwet reserve, Prome. A dense growth of young bamboo will be noticed springing up under the teak.

STATISTICAL. Under favourable conditions the rate of growth of teak in its earlier years is very rapid, a mean girth of 2 in. and a mean height of 6 ft. per annum for the first few years being not unusual in well situated and tended plantations. Later the growth becomes somewhat slower, though in plantations which have been formed in favourable localities and have been regularly tended a girth increment of 1 in. a year or more may be expected. It will be convenient to consider statistical information separately for plantations and natural forest.

1. *Plantations. Burma.* The most recent statistics of a more or less complete nature relating to the teak plantations of Burma are those compiled by Mr. F. A. Leete² from data collected up to 1909. These statistics were prepared from measurements made immediately after thinning in selected fully stocked sample plots in teak plantations of different ages in various localities. As Mr. Leete remarks, it is as yet too early to determine whether all plantations throughout the province should be grouped together in one set

¹ Forest Administration Report, Burma, 1913-14.

² Memorandum on Teak Plantations in Burma. For. Bull. new ser., No. 2, 1911.



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of curves, or different standards should be fixed in different localities. Meanwhile he has grouped them all together, and has obtained the following results :

Tectona grandis : rate of growth and number of stems per acre in teak plantations in Burma (F. A. Leete, 1909).

Age. years.	Mean girth. ft. in.	Mean height. ft.	Number of stems per acre.
10	1 3	38	530
20	2 4	62	185
30	3 1	84	95
40	3 9	96	75

Note. (1) Suppressed stems are not included ; (2) original spacing 6 ft. by 6 ft. or 12 ft. by 3 ft. giving 1,210 plants per acre.

As compared with an estimate formed by Mr. P. J. Carter in 1896, Mr. Leete's figures show a faster rate of growth in girth and a smaller number of stems per acre.

Central Provinces. Measurements made in 1896 in the Sakata and Korai plantations in Seoni gave the following results :¹

Tectona grandis : measurements in Sakata and Korai plantations, Seoni.

No.	Locality.	Approximate age. years.	Number of stems per acre.	Mean girth. ft. in.	Mean height. ft.	Volume per acre. cub. ft.
1	Sakata	26	418	1 4	44	2,289
2	"	26	707	1 0	30	1,409
3	Korai	18	696	0 10	28	866

In the Sakata plantations the trees were reported to be very dense and in need of thinning, hence the poor girth increment.

Madras. A small plantation of 1868 at Ramanapenta in West Kurnool, measured in 1911, at an age of 43 years, had a height of 60 ft. and a girth varying from 2 ft. 8½ in. to 3 ft. 6½ in. The waterfall plantation at Mount Stuart, South Coimbatore, measured at an age of 42 years, had a mean height of 68 ft. and a mean girth of 2 ft. 9 in.

In his recent working plan for the Nilambur teak plantations Mr. Bourne has given yield tables based on extensive measurements in those plantations, and containing outturn figures in considerable detail. The statement on p. 763 gives a summary of the more important figures contained in those tables.

Andamans. Measurements made in 1910 gave the following results :

Year of plantation.	Age. years.	Mean girth. ft. in.
1890	20	2 8
1889	21	2 9
1887	23	2 9
1883	27	2 5

2. *Natural forest.* (a) *Girth and height increment.* *Burma.* The statements facing p. 764, compiled from measurements recorded in the various working

¹ Working Plan for the Korai Range Forests, F. Linnell, 1896.

Tectona grandis : yield table for one acre of pure high forest, Nilambur plantations.

Age. years.	Standing crop, after thinning.			Intermediate yields : solid volume of stemwood.		Total yield : solid volume of stemwood. cub. ft.	Mean annual increment calculated on total yield : solid volume of stemwood. cub. ft.
	Number of stems.	Mean girth at 4½ ft. in.	Mean height of dominant trees. ft.	Solid volume of stemwood. cub. ft.	Periodic. cub. ft.		
I. Quality.							
5	..	12.8	41	388	..	..	..
10	266	19.9	56	732	..	504	1,236
15	179	26.4	66	1,002	374	878	1,880
20	137	31.9	74	1,247	278	1,156	2,403
25	110	37.0	81	1,471	287	1,443	2,914
30	91	41.8	87	1,688	278	1,721	3,409
35	79	46.0	93	1,901	263	1,984	3,885
40	69	50.0	97	2,111	238	2,222	4,333
45	62	53.7	102	2,316	221	2,443	4,759
50	56	57.5	106	2,513	196	2,639	5,152
55	51	61.1	110	2,696	186	2,825	5,521
60	48	64.6	113	2,868	161	2,986	5,854
65	46	68.0	116	3,032	134	3,120	6,152
70	44	71.2	118	3,188	102	3,222	6,410
75	43	74.2	119	3,336	66	3,288	6,624
80	42	77.2	121	3,478	30	3,318	6,796
II. Quality.							
5	..	10.3	30	268	..	..	..
10	322	16.0	44	511	..	312	823
15	222	21.1	54	714	249	561	1,275
20	169	25.6	62	907	201	762	1,669
25	137	29.9	69	1,083	202	964	2,047
30	114	33.9	75	1,252	195	1,159	2,411
35	97	37.7	80	1,416	187	1,346	2,762
40	84	41.2	84	1,575	172	1,518	3,093
45	75	44.5	88	1,730	155	1,673	3,403
50	68	47.6	91	1,877	139	1,812	3,689
55	63	50.4	94	2,014	129	1,941	3,955
60	60	52.9	96	2,142	104	2,045	4,187
65	58	55.2	99	2,264	88	2,133	4,397
70	57	57.3	100	2,379	64	2,197	4,576
75	56	59.3	102	2,488	39	2,236	4,724
80	55	61.2	103	2,591	18	2,254	4,845
III. Quality.							
5	..	7.8	19	148	..	..	..
10	404	12.1	32	292	..	120	412
15	290	15.8	42	429	125	245	674
20	224	19.3	50	567	122	367	934
25	182	22.8	57	694	116	483	1,177
30	151	26.2	62	815	114	597	1,412
35	127	29.4	67	930	111	708	1,638
40	109	32.4	71	1,040	103	811	1,851
45	96	35.2	73	1,143	93	904	2,047
50	86	37.7	76	1,241	79	983	2,224
55	81	39.8	77	1,332	69	1,052	2,384
60	80	41.3	79	1,416	51	1,103	2,519
65	78	42.3	81	1,496	43	1,146	2,642
70	77	43.3	83	1,570	26	1,172	2,742
75	76	44.3	84	1,640	14	1,186	2,826
80	76	45.3	85	1,704	5	1,191	2,895

Note. Volumes are calculated by the quarter-girth-squared formula, in sections of 9 ft.

plans, shows the estimated rate of growth in girth in different localities. Except in the case of the Mawku working circle of the Upper Chindwin division, these figures do not include bark thickness, for which about 2 in. should be added to the girth in each case. Nor is any allowance made for the time required for a natural seedling to establish itself; this period is usually placed at ten years, though one working plan allows fifteen years. It has been considered best to reduce all the figures to the same level by omitting the period allowed for the seedling stage, which is at the best a very rough estimate, and probably varies under different conditions. In the earlier working plans, notably those of Zigôn and Tharrawaddy, Pressler's borer was largely employed to estimate the rate of growth, and the figures obtained are probably less reliable than in most of the other working plans, where the rate of growth has been estimated from ring-countings. It may be noted that the figures given refer to trees which have grown up under natural conditions without any tending, and the rate of growth is probably slower than might be expected in regularly tended natural crops. In Tharrawaddy and Zigôn the rapid growth in the alluvial plains forests as compared with the hill forests is noticeable. This is not the case in Insein, where the soil of the plains forests is not so well drained as that of the Tharrawaddy and Zigôn divisions, and consists in places of laterite.

Central Provinces. The following statement showing the rate of growth in girth over bark and in height has been compiled from measurements made in different localities in the Central Provinces between 1909 and 1914:

Tectona grandis: rate of growth in girth and height in natural forest, Central Provinces; measurements made from 1909 to 1914.

Age. years.	Melghat, well-grown trees in favourable localities.		Saugor.		Kishen- garh felling series.		Patri- kata felling series.		Gourj- hamar felling series.		S. Chanda: Allapilli reserve.		Mirkullu blo	
	Garhakota working circle.		Kerpani felling series.		Kishen- garh felling series.		Patri- kata felling series.		Gourj- hamar felling series.		Bhimaran hill forests.		Bhimaran plains forests.	
	Girth.	Height.	Girth.	Height.	Girth.	Height.	Girth.	Height.	Girth.	Height.	Girth.	Height.	Girth.	Height.
	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
10	0 8	..	0 7	0 6	0 5	..	..	..	..	..	..	..	..	..
20	1 4	0 11	1 1	0 11	1 0	1 1	..	..	..	..	..	..	..	..
30	2 0	1 5	1 8	1 5	1 8	1 9	1 3	44	..	..	1 2	..	..	..
40	2 9	1 11	2 3	1 10	..	2 3	2 2	53	3 0	60	1 11	..	..	..
50	3 7	2 5	2				2 8	60	3 8	73	2 0	..	..	..
60							3 1	65	4 1	75	3 5	..	..	..
70							3 5	69	4 5	77	3 10	..	..	..
80							3 9	73	4 8	78	4 1	..	..	..
90							4 1	76	4 11	79	4 4	..	..	..
100							4 4	79	5 1	80	4 7	..	..	..
110							4 7	81	5 3	81	4 10	..	..	..
120							4 10	83	5 5	81	5 1	..	..	..
130							5 1	85	5 7	82	5 4	..	..	..
140							5 4	86	5 9	82	5 7	..	..	..
150							5 6	87	5 11	83	5 9	..	..	..

Mr. J. W. Best¹ has recorded the following summary of measurements of over 4,000 felled teak trees, in two local quality classes, in the Hoshangabad forests:

¹ Ind. Forester, xliv (1918), p. 408.

tinued).

[illegible]

Tectona grandis : rate of growth of natural teak, Hoshangabad, Central Provinces.

Age. years.	Local quality I (i. e. trees attaining a height of over 50 ft. in 40 years).		Local quality II (i. e. trees attaining a height up to 50 ft. in 40 years).	
	Mean height.	Mean girth at 4½ ft. from ground.	Mean height.	Mean girth at 4½ ft. from ground.
	ft.	in.	ft.	in.
5	14	7	11	3
10	21	13	18	6
15	27	17	22	9
20	33	21	26	11
25	38	25	29	15
30	43	30	32	17
35	47	33	34	20
40	50	37	36	22
45	53	40	38	25
50	56	45	40	27
55	58	47	42	30
60	60	50	44	32
65	62	52	45	34
70	62	54	47	35
75	62	55	48	37
80	62	56	48	38
85	62	56	49	39
90	62	56	49	39
95	62	56	..	..
100	62	56	..	..

Bombay. The statement on p. 766 which shows the average rate of growth in girth, has been compiled from measurements recorded in Bombay working plans. In each case bark thickness has been included ; where this has not been definitely given in the working plans it has been taken to be 0.25 in.

(b) *Taper of logs.* Mr. H. F. Blanford¹ has worked out, from numerous measurements in the Mohnyin and Mosit forests, Upper Burma, the taper of bottom logs 25 ft. in length, with the view of arriving at an estimate of the minimum girth of trees to be felled in order to produce 'Europe squares', that is, sound, straight timber, free from sapwood, at least 12 in. square and 18 ft. in length, and averaging not less than 25 ft. in length. These measurements show that the taper increases slightly with age. Allowing for sapwood and bark, the minimum girth at the thin end of the log, in order to produce these squares, is 6 ft. The measurements of taper show that a breast-height girth of 7 ft. 9.7 in., or in round figures 8 ft., is necessary to produce a girth of 6 ft. at 25 ft. above the felling wedge, that is, to produce an average 'Europe square'. Mr. Blanford's measurements are summarized as follows :

Average taper, i. e. diminution in girth to a height of 25 ft. above felling wedge, or 27 ft. 6 in. from ground.		
Girth at breast height.	Mohnyin.	Mosit.
	in.	in.
6 ft. to 6 ft. 11 in. . . .	16.1	14.1
7 ft. to 7 ft. 11 in. . . .	19.7	14.4
8 ft. to 8 ft. 11 in. . . .	23.4	15.7
9 ft. to 9 ft. 11 in. . . .	26.0	19.1

Example: in Mohnyin a tree with a breast-height girth of 8 ft. has a girth at 25 ft. above the felling wedge of 8 ft. - 23.4 in. = 6 ft. 0.6 in.

¹ (1) Working Plan for the Mohnyin Reserve, Katha, 1910-11 to 1929-30.
(2) Mosit Working Plan, Bhamo, 1910-11 to 1939-40.

(c) *Volume figures. Burma.* The average volume of marketable timber in trees of different girths and ages in the Mohnyin and Mosit working circles has been estimated by Mr. Blanford as follows :

Tectona grandis : outturn of marketable timber from trees of different sizes, Mohnyin and Mosit.

Girth at breast height. ft.	Mohnyin.		Mosit.	
	Corresponding age. years.	Average volume excluding bark. cub. ft.	Corresponding age. years.	Average volume excluding bark. cub. ft.
3	55	26	..	..
4½	77	37	..	..
6	112	54	129	62
7	144	77	155	97
7½	161	97	168	111
8	188	110	185	122
9	227	148	221	154
10	285	182	..	211
10½	314	198	..	232

Note. Ten years have been added to the age in each case, to allow for the time required for a seedling to establish itself.

The latest Tharrawaddy working plan for the Pegu Yoma forests gives the following outturn figures for dry and moist forest combined :

Tectona grandis : outturn figures, Tharrawaddy.

Girth class.	Volume of timber per tree. cub. ft.	Girth class.	Volume of timber per tree. cub. ft.
6 ft. 6 in.—6 ft. 11 in.	74	8 ft. 6 in.—8 ft. 11 in.	147
7 ft. 0 in.—7 ft. 5 in.	88	9 ft. 0 in.—9 ft. 5 in.	166
7 ft. 6 in.—7 ft. 11 in.	104	9 ft. 6 in.—9 ft. 11 in.	186
8 ft. 0 in.—8 ft. 5 in.	136	..	..

The size of logs actually brought out from the forests must of necessity depend greatly on facilities for extracting large timber, apart from the size of the trees felled. The largest average logs brought out so far in any one sub-period under working plans prescriptions are the 639 logs extracted from the Kangyi reserve of the Zigôn forest division during the sub-period 1902–3 to 1905–6, which averaged 103 cubic ft. The following statement gives the names of forests from which the largest average logs were extracted up to 1910, the averages being given by single sub-periods :

Tectona grandis : volumes of average logs extracted during single sub-periods from forests in Burma up to 1910.

Forest division.	Working circle.	Average volume of all logs extracted during single sub-periods. cub. ft.	Forest division.	Working circle.	Average volume of all logs extracted during single sub-periods. cub. ft.
Zigôn	Kangyi	103	Prome	N. Nawin	67
	Taungnyo	92	"	S. Nawin	67
	"	90	Zigôn	Bawbin	67
	Kangyi	79	Tharrawaddy	Thonzè	67
	Bawbin	73	S. Toungoo	Kabaung	67
"Tharrawaddy	Gamôn	72	"	"	66
	Kadinbilin	72	Tharrawaddy	Minhla	66
	Shwele	68	"	Môkka	66
Prome		68	Katha	Mohnyin	65
N. Toungoo	W. Swa, Sabyin, and Lonyan	68			

Note. Volume does not include bark.

Central Provinces. The following statement has been compiled from the results of measurements of 642 trees in the Allapilli forests, South Chanda :

Tectona grandis : outturn of average trees, Allapilli.

Girth at breast height.	Average volume per tree, round timber measured over bark.	Girth at breast height.	Average volume per tree, round timber measured over bark.
ft. in.	cub. ft.	ft. in.	cub. ft.
6 0	63	8 0	108
6 6	73	8 6	119
7 0	84	9 0	129
7 6	96	9 6	138

Bombay. The following is the result of a stem analysis of five teak trees made by Mr. W. A. Miller in the Kirwatti forests of Kanara :

Tectona grandis : stem analysis of five trees, Kirwatti forests, Kanara.

Age.	Mean diameter at breast height.	Mean height.	Mean volume.	Mean annual volume increment.
years.	in.	ft.	cub. ft.	cub. ft.
10	3.0	19	..	..
20	5.5	37	..	..
30	8.7	47	6.5	2.17
40	11.8	51	13.0	4.33
50	13.7	54	24.5	4.90
60	16.0	58	34.5	5.75
70	17.5	62	41.5	5.93
80	18.2	65	47.0	5.87
90	18.8	67	51.0	5.67
100	19.1	69	55.0	5.50

Mr. Miller has also recorded the following results of measurements in the forests of the Arbail Slopes, Kanara, showing the average growth of single trees :¹

Tectona grandis : growth and outturn of single trees, Arbail Slopes, Kanara.

Age.	Mean diameter.	Corresponding girth.	Mean height.	Mean volume per tree.
years.	in.	ft. in.	ft.	cub. ft.
20	5.4	1 5	44	4
40	9.2	2 5	64	10
60	12.8	3 4	75	21
80	15.6	4 1	83	46
100	18.0	4 9	90	71
120	20.0	5 3	95	89
140	21.8	5 9	100	104
160	23.4	6 1	104	118
180	24.6	6 5	107	132
200	25.2	6 7	109	144
220	..	..	110	156
240	..	..	110	..

2. *Tectona Hamiltoniana*, Wall. Vern. *Dahat*, Burm.

A moderate-sized deciduous tree with 6- to 8-angled branchlets and leaves usually in whorls of three, sometimes opposite or in whorls of four, somewhat resembling teak leaves but much smaller. Wood brown, harder and heavier than teak, of good quality, but used mainly for fuel, though sometimes for house-posts. This is a common tree in the dry zone of Burma, in localities

¹ Working Plan for the Arbail Slopes, Central Division, Kanara, 1918.

where the rainfall varies from 23 to 45 inches. It is capable of growing on poor stony soil, and is often associated with *Terminalia Oliveri*, *Acacia Catechu*, *A. leucophloea*, *Diospyros burmanica*, and other species of the dry open scrub forests of Burma. The tree is leafless for a time during the hot season. The dense tomentose corymbose panicles of small pale blue or whitish flowers appear from June to August, and the fruits ripen in the following cold or hot season; the fruit is a small nut tightly enclosed in the persistent tomentose calyx. The tree is a light-demander, coppices well, and is drought resistant. Frost does not occur in its habitat.

2. GMELINA, Linn.

Gmelina arborea, Linn. Vern. *Gumhar*, *sewan*, Hind.; *Gomari*, Ass.; *Shivan*, Mar.; *Shivani*, Kan.; *Gumadi*, Tam.; *Yemane*, Burm.

A moderate-sized to large deciduous tree with opposite, broadly ovate, acuminate, usually cordate leaves, glaucous beneath, or stellately hairy or tomentose beneath in one variety. Bark light grey, smooth, corky, inside yellow, rapidly turning brown on exposure, exfoliating in patches when old and exposing smooth paler coloured bark beneath. Wood yellowish or greyish white, even-grained, soft, light, and strong, seasons well without warping and cracking, and is very useful for planking, panelling, carriages, furniture, boxes, and carpentry of all kinds. It has been pronounced very good for match manufacture. In view of the good quality of its wood and of its rapid growth the tree is well worth more attention for plantation purposes. Under the most favourable conditions it attains a height of 100 ft. or more and a girth of 15 ft.

DISTRIBUTION AND HABITAT. The tree is distributed generally throughout the greater part of India and Burma, but is usually scattered; it is commoner in Burma than elsewhere. It is found in the moist region of Ceylon. It reaches its largest dimensions in the mixed forests of moist regions, as in Burma, the eastern sub-Himalayan tract, Assam, and elsewhere, but extends into comparatively dry regions, as in Central India. Although usually found in mixed deciduous forest, it is occasionally found in evergreen forest, and is not uncommon in sal forest. In the western Himalaya it ascends the outer hills and valleys to 4,000 ft., where it may occasionally be seen in stunted form even in somewhat dry situations. Its choice of locality is wide, but it shows a preference for moist fertile valleys; it does not thrive where the drainage is bad, while on dry sandy or otherwise poor soil it remains stunted, and is apt to assume little more than a shrubby form owing to its being repeatedly killed back by drought.

In its natural habitat the absolute maximum shade temperature varies from under 100° to 118° F., the absolute minimum from 30° to over 60° F., and the normal rainfall from 30 to 180 in. or more.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The leaves fall as a rule about January–February, the new leaves appearing in March–April. The panicles of flowers appear from February to April, when the tree is more or less leafless, or with the young leaves, and the irregular tubular corollas, about 1 in. long, dull chestnut, with a yellow lip and throat, quickly fall from the trees and cover the ground in their neighbourhood. The fruits ripen from

the end of April (Burma) to July. The fruit is a succulent ovoid or oblong drupe, 0.9–1.2 in. long, yellow when ripe, with a leathery shining pericarp, a sweetish pulp, and a hard bony stone. The stone (Fig. 294, *a*) is 0.6–0.9 in. long, ovoid, pointed at one end, usually 2-celled and 2-seeded, but sometimes 1- or 3-celled and seeded. About 40 stones average 1 oz. in weight. Seed-year records in Chittagong and in the Santal Parganas show that the tree seeds well as a rule every year. The germinative power of fresh seed is high, but if stored for a year a considerable proportion of the seed loses its vitality : a sample of fruit-stones tested at Dehra Dun, which gave 90 per cent. of success when fresh, gave only 30 per cent. when kept for one year. The highest percentage obtained from fresh fruit-stones was 112, often two and sometimes three seedlings emerging from one stone. The fruits are eagerly devoured by cattle and deer, and the stones are spread by their agency.

GERMINATION (Fig. 294, *b–f*). Epigeous, resembling that of the teak. The stone of the drupe opens by means of one or two lateral valves, the radicle emerging first and the cotyledons issuing shortly after. The stone is either left on or in the ground, or is carried up over the cotyledons, falling with their expansion.

THE SEEDLING (Fig. 294).

Roots : primary root long, at first thin, afterwards thickening considerably, terete, tapering : lateral roots moderate in number and length, fibrous, distributed down main root or more plentiful in its upper part. *Hypocotyl* distinct from and thicker than root, 0.3–0.7 in. long, terete or obscurely quadrangular, white turning green, finely pubescent. *Cotyledons* : petiole 0.1–0.2 in. long, channelled or flattened above, finely pubescent with capitate hairs : lamina 0.5–0.7 in. by 0.3–0.4 in., elliptical or ovate, emarginate, entire, somewhat fleshy, yellow turning green, finely pubescent with capitate hairs, midrib deeply impressed on upper surface, lateral veins less distinct. *Stem* erect, more or less quadrangular near the nodes, green, finely pubescent with capitate hairs ; internodes 0.5–3 in. long. *Leaves* simple, opposite, exstipulate. Petiole 0.3–1.5 in. long, channelled above, green, glabrous or finely tomentose. Lamina 1.5–3 in. by 1.2–3 in., broadly ovate, acute or acuminate, widely dentate or sinuate, base cordate, cuneate, or obtuse, with glands near the petiole, green above, glaucous beneath, glabrous or lower surface glabrescent or finely pubescent with capitate hairs on the principal veins ; lateral veins 3–5 pairs, including two prominent basal lateral veins.

Under favourable conditions the growth of the seedling is rapid, more particularly from the second year onwards. Although able to struggle against weeds more successfully than many other species, it responds to weeding by more rapid growth and increased vigour ; it also benefits by irrigation. On stiff soil its development is poor. Among damp weeds the seedlings are apt to rot during the rain.

The season's growth ceases about November, the leaves fall in December–January, and the new leaves begin to appear in February–March (northern India). From May onwards in the second season the growth is rapid. The axillary buds of the stem usually commence to sprout in the first season, and in vigorous plants side branches may reach several inches in length ; in the second year strong side branches are developed.

The seedling is fairly hardy as regards drought and frost. In frosty localities the leaves are often touched, the shoots escaping, but in grass the

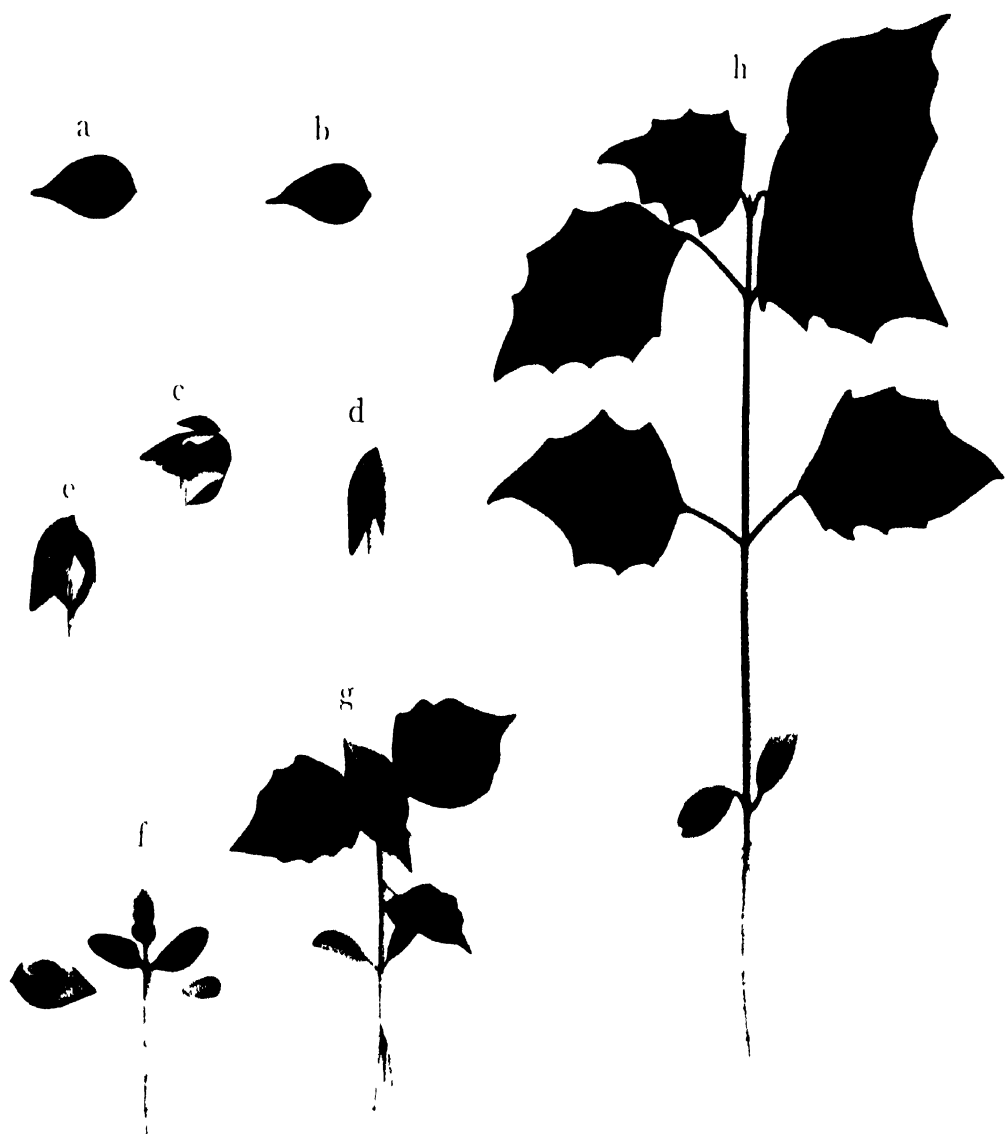


FIG. 294. *Gmelina arborea* SEEDLING $\times \frac{1}{2}$

a Stone of fruit b-f Germination stages g, h Development of seedling during first season

seedlings may be entirely killed down, though their power of recovery from the base is good. Seedlings are somewhat light-demanding, their development being poor under shade which is at all heavy. In the germinating stages crickets are often destructive, while in the sapling stage much damage is done by a boring insect which tunnels down the shoots and frequently kills the leading ones; the attack may be recognized by holes in the side of the shoot affected.

The following measurements in experimental plots at Dehra Dun give some indication of the rate of growth of young plants under different conditions :

Gmelina arborea : development of seedlings under different conditions,
Dehra Dun.

Condition under which grown (in sunny locality in each case: shade experiments failed).	Height at end of season, and other particulars.			
	1st season.	2nd season.	3rd season.	4th season.
(1) Natural conditions (fruits scattered on bare ground, uncovered)	0 ft. 7½ in.	4 ft. 0 in. (only one seedling germinated)	10 ft. 0 in.	..
(2) Natural conditions (fruits scattered on bare ground, uncovered)	Maximum 0 ft. 11 in.	..	..	..
(3) Natural conditions (fruits scattered on grassy ground)	Maximum 0 ft. 10½ in.	..	..	..
(4) Nursery plants	Maximum 1 ft. 3 in.	..	..	..
(5) Transplants of 1st season, entire roots and stem (unweeded after transplanting)	Maximum 1 ft. 4½ in.	Maximum 3 ft. 9 in.	0 ft. 9 in.-5 ft. 3 in.	13 ft.-14 ft. (maximum girth 9 in. at 3½ ft. from ground)
(6) Transplants of 1st season, entire roots and stem (unweeded after transplanting)	Maximum 1 ft. 8 in.	11 in.-5 ft. 3 in.	2 ft. 8 in.-9 ft. 6 in.	..
(7) Transplants of 2nd season, pruned stem and root	..	..	2 ft. 5 in.-3 ft. 1 in.	..
(8) Broadcast sowings, irrigated, weeded	Maximum 2 ft. 10 in. (vigorous)	2 ft. 8 in.-10 ft. 0 in. (vigorous, 33 survivors)	..	..
(9) Broadcast sowings, irrigated, unweeded	Maximum 0 ft. 5½ in. (weakly)	1 ft. 1 in. (only one survivor)	..	..
(10) Broadcast sowings, unirrigated, weeded	Maximum 0 ft. 10 in.	1 ft. 11 in.-5 ft. 4 in.	..	..
(11) Broadcast sowings, unirrigated, unweeded	Maximum 0 ft. 9 in.	1 ft. 6 in.-4 ft. 0 in.	..	..
(12) Line sowings, irrigated, weeded, thinned	Maximum 3 ft. 3½ in.	5 ft. 10 in.-8 ft. 9 in.	14 ft. 0 in.-17 ft. 10 in.	..
(13) Line sowings, irrigated, weeded, unthinned	Maximum 4 ft. 4 in.	3 ft. 0 in.-12 ft. 2 in.	8 ft. 0 in.-17 ft. 8 in. (stems less vigorous than in thinned lines)	..
(14) Line sowings, irrigated, unweeded, unthinned	Maximum 3 ft. 0 in.	4 ft. 7 in.-10 ft. 3 in.	8 ft. 0 in.-16 ft. 5 in. (stems thin and lanky)	..
(15) Line sowings, unirrigated, weeded, thinned	Maximum 4 ft. 6 in.	Maximum 10 ft. 6 in.	..	..
(16) Line sowings, unirrigated, weeded, unthinned	Maximum 3 ft. 3 in.	Maximum 7 ft. 0 in.	..	..
(17) Line sowings, unirrigated, unweeded, unthinned	Maximum 3 ft. 8 in.	0 ft. 10 in.-7 ft. 0 in.	..	..
(18) Line sowings, weeded, in combination with field crops (suppressed by crops in first season)	0 ft. 2 in.-0 ft. 10 in.	Maximum 6 ft. 4 in.	..	..

Some of these measurements indicate the value of weeding.

SILVICULTURAL CHARACTERS. The tree is a light-demander, though it stands rather more shade than the teak. It is moderately frost-hardy, and has good power of recovery when injured by frost. It does not stand excessive drought, as is shown in the case of plantations in the Panch Mahals, Bombay, on dry soil with a considerable proportion of sand, where the trees have in many cases either died outright or have died back and kept alive only in stunted bushy form. In Lahore Cantonment, however, it grows without irrigation, which not many trees are capable of doing.

It coppices very well, the coppice-shoots growing vigorously. It has not been observed to produce root-suckers to any extent, but Mr. R. N. Parker mentions that they have been produced by a tree in the Changa Manga plantation. Saplings are readily browsed by deer, which do much damage in young plantations. Cattle also browse young plants if there is an insufficiency of other fodder.

NATURAL REPRODUCTION. Under natural conditions germination takes place in the rainy season soon after the fall of the fruits. If the fruits are eaten by deer or cattle the stones are rejected during rumination; otherwise the fleshy portion soon either roots off, or is softened and washed off by rain, or is eaten away by insects, leaving the stone exposed. Numerous experiments have been carried out at Dehra Dun to ascertain the factors influencing natural reproduction, and the chief of these have been established with tolerable certainty. It is clear that, as in the case of teak, a considerable amount of alternating heat and moisture is necessary to stimulate germination, for which reason fruit-stones lying in shade which is at all heavy fail to germinate for want of the sun's heat. Secondly, it is of great importance that the stones should become buried to some extent, otherwise there is a strong risk of failure to germinate. This was confirmed many times, the seed on very rare occasions succeeding in germinating if lying on the surface of the ground; want of sufficiently continuous moisture appears to be the explanation of this. In the few cases in which germination did take place under these conditions the young seedling was usually washed away by rain before it obtained a foothold. Thirdly, clear ground forms a favourable germinating bed, particularly if it has been broken up so that the seed has a chance of becoming buried; seed lying among weeds or grass usually fails to germinate. In this connexion it may be noted that plentiful natural reproduction has been observed on abandoned *taungya* lands (temporary cultivation) in Burma.

In the forest natural reproduction is not as a rule plentiful, and as the germinative power of the seed is high the only explanation is that a combination of favourable conditions is not very frequent. Apart from the factors which favour germination, the establishment of reproduction depends on the admission of a considerable degree of light, while in grazed areas reproduction has little chance of making headway owing to the readiness with which the young plants are browsed.

ARTIFICIAL REPRODUCTION. The tree can be raised easily either by transplanting from the nursery or by direct sowings; the latter have proved much more successful than the former at Dehra Dun. It is also said that large cuttings planted during the rainy season strike well; this possibly applies to a damp climate or where irrigation is carried out, but cuttings tried at

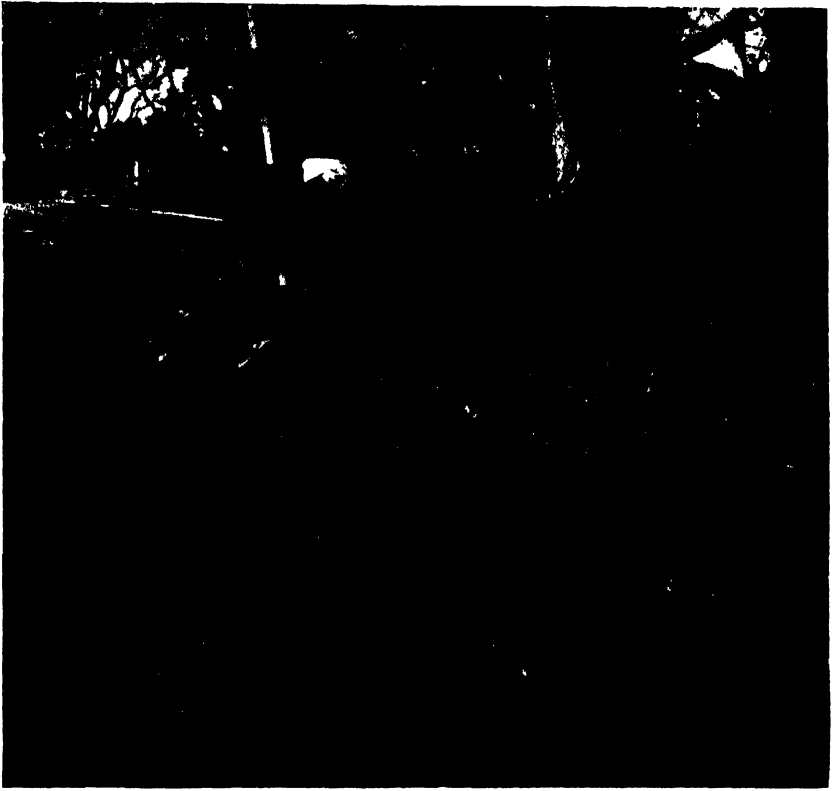


FIG. 295. *Gmelina arborea*, irrigated line sowings 5 months old, maximum height 4 ft. 5 in., Dehra Dun.



FIG. 296. *Gmelina arborea*, irrigated line sowings, end of third season, height 14–18 ft., Dehra Dun.



FIG. 297. *Gmelina arborea*, unirrigated weeded line sowings, end of third season height 10 ft., Dehra Dun.
Staff shows feet.

Dehra Dun, although they sprouted and remained alive for some time, died off in the dry season.

For transplanting purposes the fruit-stones should be sown in drills in the nursery as soon as the fruit ripens, as a rule shortly before the rainy season commences. No shading is necessary, but the beds should be regularly watered and weeded. The seedlings ordinarily begin to appear in about two to three weeks.

Transplanting may be carried out either in the first or in the second rainy season. In the former case small plants about 3 or 4 in. high should be used, the seedlings being separated and planted out during damp weather with roots and stems intact. If the plants are to be kept for a year in the nursery they should be separated and pricked out to about 9 in. apart in the first rains while still small. Next rainy season they should be planted out with the stem pruned down to about 2 in. from ground-level, and the root trimmed to a length of about 1 ft.; they stand this treatment well. Subsequently it may be necessary to prune off surplus shoots springing from the stumped plants. For plantation purposes a spacing of 6 ft. by 6 ft. is ordinarily suitable.

At Dehra Dun direct sowing in lines has proved much more successful than transplanting, and has given excellent results. Where irrigation is possible this stimulates growth, but unirrigated line sowings have also given very good results, always provided the lines are kept regularly weeded. Items (8) to (18) of the statement under 'seedling' on p. 771 give some idea of the growth under different methods of sowing, and Figs. 295, 296, and 297 show line sowings in different stages. A distance of 10 to 12 ft. between lines and an interval of about 1 ft. between fruit-stones will be found sufficient, and 1 lb. of fruit-stones may be allowed roughly for 600 ft. of line. The stones can be most conveniently sown along a shallow furrow or dibbled in with the aid of a pointed stick, and lightly covered with earth in either case. Irrigated line sowings are carried out in the manner described for irrigated sowings of *Dalbergia Sissoo* (Vol. I, p. 306). Of unirrigated line sowings the most satisfactory are those carried out with the aid of field crops, but care should be taken to leave a width of about 2 ft. along the lines unsown with cereals, the latter being sown in the intervening spaces. If the field crops are sown continuously over the area the seedlings suffer from suppression during the first season, and may even be killed off if the cover is dense. In experiments carried out at Dehra Dun the crop employed was the lesser millet (*Eleusine coracana*), which was sown in May, formed a dense crop 3 to 3½ ft. high, and was reaped in October; the lines of *Gmelina* were sown in June. In line sowings along with field crops it is preferable to allow cultivation for a second year, the cultivator keeping the lines weeded, as this saves expense and serves to keep the ground clear of weeds for a longer period than if cultivation is done for one year only; at the same time the longer cultivation is permitted the smaller the area which can be planted annually by a given number of cultivators, and this may be a matter of importance if the area to be planted is large and the number of cultivators is limited.

In sowings of any form certain supplementary operations are essential to success. Weeding is of great importance, and hence the advantage of sowing in regularly spaced lines. Weeding should commence during the first season,

and for the first year or two clean weeding with slight loosening of the soil stimulates growth where this is a matter of importance, as in dry localities ; after the first year or two all that is necessary is to free the plants from overhead cover. During the first rainy season it is advisable to pull up duplicate seedlings and plant them to fill up gaps ; the pulling up of the surplus seedlings may be done in the ensuing dry season, but it will then be impossible to utilize them for filling gaps. Thinnings to relieve congestion in the lines should commence about the third year if necessary, the strongest and best-shaped plants being retained and the weakly and badly shaped ones removed ; this operation is responded to by better growth.

As regards the location of plantations, it cannot be emphasized too strongly that plantations of *Gmelina arborea* can never pay unless rapid growth and fairly large dimensions are ensured. Plantations of this species therefore should never be made except on fertile soil in a climate at least moderately damp. Poor dry or shallow soil as well as badly drained clayey ground should be carefully avoided, as the plants will always remain stunted. Plantations formed in the dry climate of the Panch Mahals in Bombay, on dry somewhat sandy soil, have proved a complete failure, the plants remaining stunted or dying out altogether. On fertile loam in a fairly moist climate, however, plantations of this species, if properly formed and carefully tended, should be a source of considerable profit, as the wood cannot fail to command a good sale if placed on the market in regular annual quantities.

Mr. C. G. E. Dawkins ¹ has described some successful experiments in raising plantations of *Gmelina arborea* in the Katha district of Upper Burma. He notes that for transplanting purposes the seed should be sown in the nursery by the middle of May at the latest, and the seedlings should be transplanted when 9 in. to 1 ft. in height, those which have grown too large being discarded. For transplanting in the cold season the seed should be sown in the nursery in September, and the seedlings should be transplanted in the end of October or the beginning of November, only the strongest plants being used. The great advantage of planting during the cold season, which gave 90 per cent. of success, is that the growth of grass is less luxuriant than during the rainy season, and the seedlings have the advantage of a good start. A successful plantation was formed in 1916 on a flat area with a strong growth of grass. This area was cleared in February, burnt in April, planted 6 ft. by 6 ft. about the end of May, and weeded once the following rainy season ; by November the plants were 4 to 5 ft. in height. Next rainy season the plantation was weeded once in July, after which no further weeding was found necessary, owing to the fact that the crowns had closed up and suppressed the grass. In 1918 the plantation was thinned heavily, and in January 1919 the remaining stems had an average girth of 11 in., the largest tree having a girth of 20 in. and a height of 36½ ft. ; there was marked dying off of side branches. An experimental *taungya* plantation also proved highly successful, the field crop employed being hill rice ; it was found advisable, however, to sow the *Gmelina* seeds late in order to prevent the rice from becoming suppressed.

These experiments included also direct sowing, good results being obtained both by dibbling and by broadcast sowing. Seed dibbled 6 ft. by 6 ft. in the

¹ Ind. Forester, xlv (1919), p. 505.

middle of May, four or five seeds at each peg, resulted in a strong growth of plants, some of which reached a height of 11 to 12 ft. by the end of the rainy season, forming a complete canopy. Experimental broadcast sowing carried out in 1919 gave remarkable results. An abandoned *taungya* of 1917 was cleared of weed-growth and rather incompletely burnt in April 1918; next month the débris was removed, the soil was lightly raked, and seed was sown broadcast, about 45 lbs. to the acre. This resulted in a thick pure crop of *Gmelina* seedlings which killed out the weeds, rendering weeding unnecessary; in places the crop was 8 to 9 ft. high by October. The total cost of establishing the plantation was only Rs. 3-8-0 per acre, which could probably be reduced by employing only half the quantity of seed, spacing roughly 3 ft. apart, and sowing three seeds at each stake.

These experiments included the mixing of *Gmelina* with teak, but the former always became dominant and suppressed the teak.

SILVICULTURAL TREATMENT. This species is well adapted for treatment as coppice, the growth of which is rapid. The uncertainty of natural reproduction renders it difficult to rely on any system of high forest producing regular yields of this timber except by the system of clear-felling with artificial reproduction. In this case it is probable that the best results will be attained by growing it in mixture with a shade-bearer of somewhat slower growth, to act partly as a protection to the soil and partly as a means of preventing unnecessary branching in the *Gmelina*, which is somewhat prone to form low side branches unless drawn up.

RATE OF GROWTH. The growth is fast. Gamble's specimens averaged 4 rings per inch of radius, giving a mean annual girth increment of 1.57 in. Gamble also mentions the following cross-sections in the Bengal museum: (1) 10 rings for a mean diameter of $10\frac{1}{2}$ in., or rather less than 2 rings per inch of radius, giving a mean annual girth increment of 3.3 in.; (2) 27 rings for a diameter of 14 in., or nearly 4 rings per inch of radius, giving a mean annual girth increment of 1.63 in. A cross-section from the United Provinces in the silvicultural museum at Dehra Dun showed 35 rings for a girth of 3 ft. 9 in., giving a mean annual girth increment of 1.3 in., or less than 5 rings per inch of radius.

A plantation in the Panch Mahals, Bombay, which had suffered much from drought, showed when six years old a maximum height and girth of 18 ft. and 12 in. respectively, which is very fair considering the unsuitable climate.

In the young experimental plantations of Dehra Dun, measurements of which have been given above under 'seedling', the growth on the whole is probably unsurpassed by that of any of the numerous other species experimented with. The measurements already quoted in respect of young plantations in Katha, Upper Burma, also show remarkable growth. In this locality Mr. Dawkins found that seven naturally grown trees produced a mean girth of $4\frac{1}{2}$ ft. in twenty-one years, and he estimated that tended plantations would attain a mean girth of 6 ft., with about 100 stems per acre, in thirty years. A natural seedling in the forest near Kotdwara, United Provinces, which had a height of 5 ft. in January 1913, was remeasured in November 1916 and found to have a height of 22 ft.

Coppice growth is also rapid. A stool in a coupe fourteen years old in the Gorakhpur district, United Provinces, had produced three coppice-shoots 42 ft. high and 3 ft., 2 ft. 3 in., and 1 ft. 8 in. in girth respectively, while dominant sal coppice shoots near it had a maximum height of 35 ft., and averaged 1 ft. 6 in. in girth. In the Koderma forest, Hazaribagh, Mr. Haines in 1916 measured a coppice-shoot eleven years old with a girth of 1 ft. 6 in., the maximum girth of sal coppice-shoots near it being 1 ft. 3 in.

3. VITEX, Linn.

A genus containing about 15 Indian species of trees or shrubs with opposite digitately 3- or 5-foliate leaves; it includes some useful timber trees. Silviculturally this genus has as yet received little study.

Species 1. *V. Negundo*, Linn.; 2. *V. altissima*, Linn. f.; 3. *V. pubescens*, Vahl; 4. *V. peduncularis*, Wall.; 5. *V. Leucozylon*, Linn. f.; 6. *V. glabrata*, R. Br.

1. *Vitex Negundo*, Linn. Vern. *Shiwāli*, Hind.; *Marwan*, Pb.; *Nirgud*, Mar.; *Nochi*, Tam.; *Vavili*, Tel.

A deciduous shrub with 3- or 5-foliate leaves, very common, and often gregarious, throughout the greater part of India, extending into dry regions and ascending to 5,000 ft. in the outer Himalaya. Abundant in open waste places, and as a hedge plant along roads and between fields. It is a useful plant for afforestation work, producing root-suckers and growing readily from cuttings. It is not usually browsed. The twigs are used for wattle-work and rough basket-work. Growth, according to Gamble, 7 rings per inch of radius, giving a mean annual girth increment of 0.9 in.

2. *Vitex altissima*, Linn. f. Vern. *Bulgi*, *mairole*, Kan.; *Mayilei*, Tam.

A large or very large tree with a dense crown, quadrangular branchlets, and 3-foliate, rarely 5-foliate leaves. Bark grey, scaly, yellow and fibrous inside. Wood greyish brown, hard, close-grained, much in demand for building, furniture, &c. The tree is an important one in western and southern India, and is common both in evergreen and in deciduous forests of the Western Ghats, as well as in open dry forest in parts of the Deccan and Travancore; also in Ceylon. Flowers, April–May; fruits, July–August. The fruit is a small purple drupe. The tree stands a moderate amount of shade, especially in youth; it produces root-suckers. Growth, according to Gamble, 8 to 9 rings per inch of radius, giving a mean annual girth increment of 0.7 to 0.78 in.

3. *Vitex pubescens*, Vahl. Syn. *V. arborea*, Roxb. Vern. *Nemali adugu*, Tel.; *Myladi*, Tam.; *Kyetyo*, Burm.

A moderate-sized to large tree with quadrangular branchlets and 3- or 5-foliate leaves. Wood very hard and close-grained, durable and useful. Forests of southern India, extending north on the east side to Orissa; Sylhet, Burma in upper mixed deciduous forests, Andamans. In southern India it is common chiefly along the banks of streams. Growth, according to Gamble, 8 to 10 rings per inch of radius, giving a mean annual girth increment of 0.63 to 0.78 in.

A tree referred to by Mr. A. Rodger¹ under the name of *kyungauknwè*

¹ Working Plan for the Tagaung Working Circle, Ruby Mines Division, 1912, pars. 14 and 15.

in the forests of the Ruby Mines district, Upper Burma, perhaps belongs to this species. He describes it as occurring on fertile slopes along with well-grown teak, *Xylia dolabriformis*, *Terminalia tomentosa*, *Pterocarpus macrocarpus*, *Anogeissus acuminata*, *Pentacme suavis*, and other species, as well as various bamboos; also in dry stunted forest on poor shallow soil with *Diospyros burmanica*, *Terminalia Oliveri*, and the species already mentioned, teak being very scarce and of small size and the chief bamboo being *Dendrocalamus strictus*.

Mr. G. R. Jeffery¹ refers to this tree in the same district in the following words: 'Allied to teak and possessing many of the properties of teak, durable, light (floating in fresh water), even-grained but rarely attains sufficient dimensions or number to be worth extracting. Has a decided demand in Mandalay, which would be much greater were a regular supply obtainable. The tree has the appearance of a very slow growth and reproduction does not seem good.'

4. *Vitex peduncularis*, Wall. Syn. *V. alata*, Roxb. Vern. *Boruna*, Beng.; *Osai*, Ass.; *Kyetyo*, *pazin-nyo*, Burm.

A moderate-sized to large tree with trifoliate leaves, the petioles being winged in young plants and coppice-shoots. Wood hard, close-grained, used for posts and beams, yokes, &c. A tree of the eastern sub-Himalayan tract, Assam, Chota Nagpur, Orissa, and the Circars; common in upper mixed and tropical forests in many parts of Burma. Haines says that in Chota Nagpur it occurs in Singhbhum and Gangpur, especially along streams, but also on northern rocky slopes, and that in Manbhum and Hazaribagh it is very common and attains large size on the northern slopes of Parasnath; also in Koderma, Palamau, and the Santal Parganas (frequent). Flowers, March–June; fruits, August–September. The fruit is a small drupe with a 3- or 4-celled stone. Growth, according to Gamble, 6 to 8 rings per inch of radius, giving a mean annual girth increment of 0.78 to 1.05 in.

5. *Vitex Leucoxylon*, Linn. f. Vern. *Songarbi*, Mar.; *Hole-lakki*, *senkani*, Kan.; *Lokki*, Tel.

A small or large deciduous tree with a short thick trunk and spreading crown. Bark smooth, light-grey. Wood light greyish brown or pinkish, durable. Indian Peninsula from the Chanda district southwards, chiefly along banks of streams, Kanara and the Konkan. Flowers, February–March; fruits, June (Bourdillon).

6. *Vitex glabrata*, R. Br. Syn. *V. Leucoxylon*, Kurz. Vern. *Goda*, Beng.; *Tauksha*, Burm.

A large deciduous tree with 5-foliate leaves. Bark smooth, white. Wood grey, moderately hard, close-grained, durable, of good quality, used for cart-wheels. Assam, Chittagong, Burma, Andamans; also in the Rajmahal hills, very local (Haines). This is a common and conspicuous tree in the upper mixed deciduous forests of Burma, and is also fairly common in certain types of lower mixed forest, preferring well-drained ground; it is a common companion of the teak. Flowers, April–June; fruits, June–July. The fruit is a drupe about 0.5 in. long. Growth, according to Gamble, averaging 6 rings per inch of radius, giving a mean annual girth increment of 1.05 in.

¹ Working Plan for the Hintha Working Circle, Ruby Mines Division, 1909, par. 13.

4. PREMNA, Linn.

This genus contains over 30 Indian species of trees, shrubs, and climbers, of which none is of any great importance and many are rare. Silviculturally the trees have not been studied in detail; they may yet become important as furnishing close-grained woods suitable for the manufacture of bobbins.

Species 1. *P. tomentosa*, Willd.; 2. *P. pyramidata*, Wall.; 3. *P. bengalensis*, Clarke; 4. *P. latifolia*, Roxb.

1. *Premna tomentosa*, Willd. Vern. *Narvu*, Tel.; *Podanganari*, Tam.

A moderate-sized deciduous tree with branchlets and leaves densely stellate-tomentose. Bark light greyish brown. Wood smooth, close-grained, suitable for turning and carving (Gamble). Central and southern India; common in the Deccan and in the drier parts of southern India. Flowers with the young leaves in March–April; fruits, June (Bourdillon). The fruits are small drupes arranged in terminal cymes. The tree is not readily browsed by goats.

2. *Premna pyramidata*, Wall. Syn. *P. tomentosa*, Kurz. Vern. *Kyunbo*, *kyunnalin*, Burm.

A moderate-sized deciduous tree with branchlets and under sides of leaves softly stellate-tomentose. Bark light greyish brown. Wood hard, close-grained, suitable for turning and carving. A tree common throughout Burma in dry and upper mixed deciduous forests. Growth, according to Gamble, 4 to 8 rings per inch of radius, giving a mean annual girth increment of 0.78 to 1.57 in.

3. *Premna bengalensis*, Clarke.

A small or moderate-sized tree, closely allied to *P. pyramidata*, and possibly not specifically distinct. Eastern sub-Himalayan tract, chiefly on river-banks, Assam. Growth, according to Gamble, 3 to 5 rings per inch of radius, giving a mean annual girth increment of 1.26 to 2.1 in.

4. *Premna latifolia*, Roxb. Syn. *P. viburnoides*, Wall.; *P. mucronata*, Roxb. Vern. *Bakár*, Hind.

A small deciduous tree with thin light grey bark. Sub-Himalayan tract, Indian Peninsula, and Burma, chiefly in rather dry mixed deciduous forest. In the western sub-Himalayan tract it is often found in the mixed forest which marks the transition stage between the riverain forest of *Acacia Catechu* and *Dalbergia Sissoo*, and the final stage of sal forest on the more elevated lands. In northern India the tree is leafless from February to April. The corymbose inflorescences appear from April to June, and the fruit, a small drupe, ripens in the cold season. The remains of the infructescences persist on the trees long after the fruits fall. A cross-section in the silvicultural museum at Dehra Dun showed 43 rings for a girth of 2 ft. 11 in., giving a mean annual girth increment of 0.81 in.

5. CALLICARPA, Linn.

This genus consists mainly of shrubs, and the only species of some little interest is the following:

Callicarpa arborea, Roxb.

A small or moderate-sized tree with the branchlets, under sides of leaves,

and inflorescences densely tomentose with soft stellate hairs. Wood moderately hard, even-grained, resembling that of *Gmelina* (Gamble). The tree is a familiar one in the eastern sub-Himalayan tract, where it springs up readily on burnt savannah lands when they first come under fire-protection; being a strong light-demander it soon becomes ousted by other trees. In Burma it comes up frequently in deserted *taungya* lands. The corymbose cymes of small lilac or purple flowers appear from April to June, and the fruit, a small drupe, ripens from August to November or sometimes later. Growth, according to Gamble, 5 rings per inch of radius, giving a mean annual girth increment of 1.26 in.

6. AVICENNIA, Linn.

Avicennia officinalis, Linn. Syn. *A. tomentosa*, Wall. White mangrove. Vern. *Tiwar*, Mar.; *Ipai*, Kan.; *Baen*, Sundarbans; *Madda*, Tel.; *Thamè*, Burm.

A large evergreen shrub or small tree of the mangrove swamps along the coasts and tidal creeks of India and Burma. It is one of the commonest of the Indian mangrove swamp species, growing gregariously, and often forming an extensive bushy growth, conspicuous from its grey foliage, and when in flower from its bright yellow inflorescences. In the Sundarbans it occurs in the inland parts of the littoral forest, and is characteristic of *bhils*, or moist depressions. It is common along the coasts of both sides of the Indian Peninsula as well as of Chittagong, Arakan, and Burma. In the Sittang estuary it sometimes forms 60 to 70 per cent. of the stock, and reaches a height of 25–30 ft. with a girth of 2–3 ft.

The wood has a peculiar structure, consisting of alternate layers of pore-bearing tissue and loose large-celled tissue without pores. It is brittle, and is used only as fuel, but in some localities it is an important fuel species.

The paniced heads of yellow flowers appear from March to June, and the fruit ripens from August to October. The fruit is a compressed ovoid one-seeded capsule 1–1.5 in. long, dehiscing into two thick valves. The large fleshy cotyledons fill the fruit. The seeds germinate immediately they fall, or even on the tree. A thick densely hairy hypocotyl elongates, from the lower end of which a number of rootlets appear, the shoot being produced from its upper end.

The seeds are buoyant, and are thus able to spread by the agency of water; about October the tidal creeks are often full of the large seeds floating on the surface of the water, and most of this seed will be found to be germinating. To collect the seed for artificial reproduction, the best method is to drag with a small net, and throw the seed into a canoe, partly filled with water, which should then proceed straight to where the seed is to be sown, the seed being sown without delay. In Madras it is usual to sow the seed broadcast, the best time being between new moon and full moon, when the tides are lowest; the sowing is done when the tide has run out and there is no water on the ground, otherwise there is danger of the seed floating away.¹

Under favourable conditions the tree regenerates freely from seed. The necessary conditions appear to be frequent flooding and absence of dense low

¹ Working Plan for the Corringa Reserved Forest, Godavari District, H. F. Wood, 1902.

cover, which the seedlings do not tolerate. Thus a lowering of the water-level results in a cessation of reproduction, while a dense growth of *Acanthus ilicifolius*, prevalent in some localities, tends to kill out the seedlings. The tree does not coppice well. Its lateral roots spread in all directions through the mud in which it grows, and send up a plentiful crop of pneumatophores : Mr. A. W. Lushington has observed that in the Kistna mangrove forests these ultimately develop leaves and become trees.¹ This has not been recorded in any other locality, but in view of the poor coppicing power of the species it is a question of importance which requires further investigation in different localities.

7. LANTANA, Linn.

This genus contains about 50 species of tropical or sub-tropical shrubs, chiefly American. The only indigenous Indian species is *L. indica*, Roxb. (Syn. *L. dubia*, Wall.), a pubescent unarmed shrub with light purple, yellow or white, almost scentless flowers, found throughout the greater part of India. The plant known in India as the lantana, which has spread with alarming results over extensive tracts of country, is *L. aculeata*, Linn., a species introduced from tropical America.

Lantana aculeata, Linn. Syn. *L. Camara*, Linn.

A shrub with recurved prickles on the stems and branches, leaves with a strong odour of black currants when crushed, and orange-coloured flowers. The fruits are small blackish drupes and are readily devoured by birds and by squirrels, rats, jackals, and other animals, and the seeds are spread far and wide by their agency. The flowers and fruits are produced in great abundance at most seasons of the year. The shrub forms a very dense impenetrable growth many feet high, the prickly branches interlacing and forming a close network, while under luxuriant conditions of growth the plant becomes scandent, climbing into the crowns of trees.

A native of tropical America, lantana is said to have been first introduced into India as an ornamental and hedge plant in the first half of last century. It has since spread over a large part of southern India and over some other portions of the Peninsula, notably Berar and parts of Bombay. More recently it has become invasive in certain parts of northern India, for instance in the *bhabar* tract round Haldwani in the United Provinces and in the outskirts of Dehra Dun. It has spread to a considerable extent in the neighbourhood of Shillong, and unless kept in check is likely to extend throughout the Khasi and Jaintia hills. It has also succeeded in gaining a foothold in some parts of Burma, and indeed wherever conditions are at all favourable to its growth it spreads with alarming rapidity, and areas which in one year may contain only a few bushes sparsely dotted about will often become covered with a dense impenetrable mass of lantana within the space of a few years. Grazing-grounds thus become ruined in a short space of time, since the dense growth not only prevents the access of cattle, but also kills out grass. The plant is not readily browsed by cattle ; goats and camels occasionally nibble the very young leaves, but only when there is no other fodder at hand. Horses have been observed to eat it. The plant flourishes under varying climatic conditions,

¹ Inspection Notes, 1910.

from moist regions where the rainfall exceeds 200 in. to comparatively dry localities where it is as low as 30 in. It flourishes equally well on flat and on hilly ground, and on a variety of soils, including poor gravel and laterite. The plant is light-loving, but will grow under moderate shade. It is very tenacious of life, coppicing vigorously and producing root-suckers, which necessitates very thorough uprooting to prevent the reappearance of shoots. It regenerates freely from seed, and a severe fire or a succession of fires is necessary to prevent seedlings appearing in profusion. It burns readily, even when green, and after a fire it recovers rapidly, soon becoming as dense as ever.

Nowhere has the lantana become so troublesome as in the south-western portion of the Indian Peninsula, in Coorg, parts of Mysore, the Nilgiris, and elsewhere. In Coorg alone the estimated areas of different classes of land infested by lantana in 1912 were : private land, 70,400 acres, of which 35,000 acres had been cleared ; Government waste land, 40,000 acres ; reserved forests, 74,000 acres. An extensive scheme for eradicating lantana over an area of 63,200 acres in reserved forests and other Government lands in Coorg was drawn up in 1914, but owing to the outbreak of war in that year the scheme was held in abeyance. This scheme, extending over a period of eleven or twelve years, was estimated to cost Rs. 4,40,000. This figure indicates the magnitude of the task involved in dealing with the pest once it spreads, and the necessity for eradicating it as soon as it makes its appearance in any locality and before it gets out of control. So serious has the lantana question become in Coorg that it has led to the passing of a special enactment entitled *The Coorg Noxious Weeds Regulation, 1914*.

The eradication of lantana in Coorg has been the subject of detailed experiment by Mr. H. Tireman, who has published an interesting paper on the subject.¹ The most practicable method so far evolved is to burn the lantana about February or March, cut it about a foot above ground, roll the cut material away from the stumps and burn it, the stumps being then dug up at the commencement of the rainy season when the ground is soft ; the lantana is shallow-rooted, and in many cases the stumps can be pulled up by hand in soft ground. Uprooting of the regrowth is necessary for two or sometimes three or four years after the first cutting. The average cost of the work is Rs. 7 to Rs. 8 per acre for the principal clearing, or where the lantana is exceptionally dense as much as Rs. 12 per acre. For uprooting the regrowth the cost varies from 12 annas to Rs. 1-8-0 per acre in the second year, and is about 6 annas in the third year, and slightly less in the fourth year.

In parts of Madras elephants have been trained to pull up lantana, the full-grown animals pulling the shrubs up by curling their trunks round them, and the younger ones pulling at a chain at the end of which is a hook fixed into the roots of the shrub ; this operation, however, requires to be followed by a further eradication by hand, repeated at intervals. In practice the use of elephants is possible only on a limited scale.

The question of destroying lantana or preventing its spread by the aid of natural insect enemies, both indigenous and introduced, is under investigation, but the introduction of foreign insect enemies, such as the *Agromyza* fly, which destroys lantana seed in the Hawaiian Islands, is a measure requiring

¹ Ind. Forester, xlii (1916), p. 385.

to be carried out with great caution owing to the danger of the insect spreading to other host plants of valuable species.

Although the lantana is a serious pest under many conditions, it is not always to be regarded as devoid of good qualities of any kind. Outside forest tracts the principal charges against it are that unless kept in check, often at considerable cost, it quickly overruns and monopolizes waste lands, grazing-grounds, cultivated land left fallow for a short time, and coffee and other plantations, and owing to the high cost of eradicating it it is a serious check to the spread of cultivation; in the neighbourhood of cultivated or village lands it harbours pigs, which destroy the cultivators' crops, and dangerous carnivora, which devour his cattle; round stations, cantonments, and villages it creates insanitary conditions.

Within the forest its effects vary to some extent with the class of forest concerned. In deciduous forests if fire enters a lantana-infested tract, which it is almost certain to do periodically, the conflagration is so intense that trees of all sizes may be killed outright, and immense damage to the crop may result. It is quite impossible to extinguish a fire raging through a thick growth of lantana, and two or three years after a severe fire the weed is as dense and luxuriant as ever, and profits by the opening of the overhead canopy. Again, natural reproduction of the light-demanding species, which are often the most valuable species, is effectually checked. Even sandal seedlings cannot survive long under a really dense crop of lantana. Still, when the lantana is removed in the manner described above, natural reproduction of tree species comes up plentifully on the cleared areas; lantana undoubtedly enriches the soil, and forms a clean germinating bed very favourable to natural reproduction when light is admitted. Mr. Tireman, in his paper already referred to, gives instances of profuse reproduction of *Anogeissus latifolia* on lantana areas from which the weed has been cleared after repeated burning, while teak, *Dalbergia latifolia*, *Pterocarpus Marsupium*, and other valuable species also regenerate freely on such areas.

Although fires are not so liable to occur in the evergreen as in the deciduous forests of southern India, they do sometimes take place in the former in dry years, and the damage done may be considerable owing to the susceptibility of the evergreen species to injury; in the event of fire an undergrowth of lantana may therefore prove to be a serious menace. On the other hand, although lantana persists in evergreen forest, it does not become luxuriant when the canopy is dense and may in time be killed out, while seedlings of the shade-bearing evergreen species are better able to establish themselves under its cover than those of the more light-demanding deciduous species. Thus except for the danger of fire, which is not always present, lantana in evergreen forests is not, as a rule, the serious pest which it may become in deciduous forests.

Although a serious scourge under many conditions, there are cases where the effects of lantana are beneficial to the forest. Owing to its soil-improving capacity it is a useful plant on poor shallow rocky soil. Where not too dense it may serve as a useful nurse to valuable species, and instances have been noted where it has been of considerable help in the establishment of sandal reproduction; it is sometimes held that lantana is connected with the spike

disease of sandal, a question which is discussed under *Santalum album*. So far as the forest is concerned, in areas where it has already monopolized the ground, the problem to be solved is how best to take advantage of its beneficial qualities and to minimize its injurious effects. Complete eradication over large areas is certainly a most expensive operation, but it may be justified in order to prevent the further spread of the pest, or where the risk of damage by fire is very serious, that is, where the forest crop is a sufficiently valuable one, for it may be regarded as almost certain that a lantana-infested area will be overrun with fire sooner or later. In Coorg, at all events, the forest management aims at a vigorous war of extermination against the lantana. On the other hand, the eradication of lantana over definite coupes annually, combined with the complete restocking of the areas taken in hand with valuable species by natural and artificial means, would be a satisfactory method of taking advantage of the special qualities of the lantana as an aid to reproduction. Apart from the question of fire, however, objection might be taken to partial eradication of this kind on the ground that the uncleared portions of the forest will remain centres of infection to cultivated lands in the neighbourhood or to recently felled coupes in the forest. The matter still requires much study, particularly in the direction of ascertaining the conditions of light and other factors under which lantana is unable again to take possession of the ground when it has once been eradicated and where its presence is undesirable. The planting or underplanting of an existing forest crop with heavy-foliaged species under which the lantana cannot thrive, is indicated as a possible subject for experiment. *Ficus elastica* has been tried for this purpose in Madras, but the successful establishment of this tree was not effected, and the experiment came to nothing. Mr. Tireman notes that the castor-oil plant checks the growth of the lantana considerably, but does not kill it.

Suggestions have been made that the lantana might be utilized commercially for the distillation of essential oil from its leaves or perfume from its flowers; there may be possibilities in this direction. It is already used to some extent as fuel by villagers, but the amount consumed is negligible compared with the enormous quantities available.

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THE SILVICULTURE
OF
INDIAN TREES

VOLUME III

Lauraceae to Coniferae

OXFORD UNIVERSITY PRESS
LONDON EDINBURGH GLASGOW NEW YORK
TORONTO MELBOURNE CAPE TOWN BOMBAY
HUMPHREY MILFORD
PUBLISHER TO THE UNIVERSITY

THE SILVICULTURE OF INDIAN TREES

BY

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VOLUME III

Lauraceae to Coniferae

PUBLISHED UNDER THE AUTHORITY OF HIS MAJESTY'S
SECRETARY OF STATE FOR INDIA IN COUNCIL

OXFORD
AT THE CLARENDON PRESS
1921

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ORDER XLVII. LAURACEAE

An order largely represented in India by trees and shrubs, usually aromatic, for the most part evergreen and often shade-bearing. A very large proportion of the members of this order are little known. It contains a few timber trees of interest and also certain species yielding aromatic products of commercial importance; of the latter the most important are the cinnamon tree, *Cinnamomum zeylanicum*, Breyne, indigenous to India, and the camphor tree, *C. Camphora*, Nees, often cultivated.

Genera 1. BEILSCHMIEDIA, Nees; 2. MACHILUS, Nees; 3. PHOEBE, Nees; 4. CINNAMOMUM, Bl.; 5. LITSAEA, Lam.

1. BEILSCHMIEDIA, Nees.

Ten Indian species, chiefly evergreen.

Beilschmiedia sikkimensis, King. Vern. *Tarsing*, Nep.

A large evergreen tree, usually tall with a straight clean cylindrical bole, found in Sikkim and Bhutan, chiefly between 5,000 and 6,000 ft. and occasionally higher. Manson (Darjeeling working plan) says seedlings are not very common; they grow well under shade, are occasionally found in grassy blanks, and are easily raised in nurseries.

The fruit, an ellipsoidal 1-seeded berry, ripens in June–July. Wood soft, used for building, tea-boxes, &c. Growth, according to Gamble, 5 to 9 rings per inch of radius, giving a mean annual girth increment of 0.7 to 1.26 in.

2. MACHILUS, Nees.

Eleven Indian species of evergreen trees.

Species 1. *M. odoratissima*, Nees; 2. *M. Duthiei*, King; 3. *M. Gamblei*, King; 4. *M. edulis*, King; 5. *M. bombycina*, King.

1. *Machilus odoratissima*, Nees. Vern. *Kawla*, *dalchini*, Hind.

A moderate-sized evergreen tree with oblong-lanceolate leaves 4–6 in. long, dark green and shining above, slightly glaucous beneath. Bark dark brown. Wood grey, moderately hard, apparently not used as timber.

DISTRIBUTION AND HABITAT. Outer Himalayan valleys and hill slopes from the Sutlej eastwards, at 2,000–7,000 ft., Khasi hills, and hills of the Ruby Mines district, Upper Burma. The tree is found mainly in moist ravines and shady places.

FLOWERING AND FRUITING. The panicles of small flowers appear in March–April, and the fruit ripens about June. The fruit (Fig. 298, a) is a one-seeded ellipsoidal berry about 0.6 in. long, dark purplish blue with a waxy bloom and a fragrant pulp. The fruits fall from the tree as soon as they ripen,

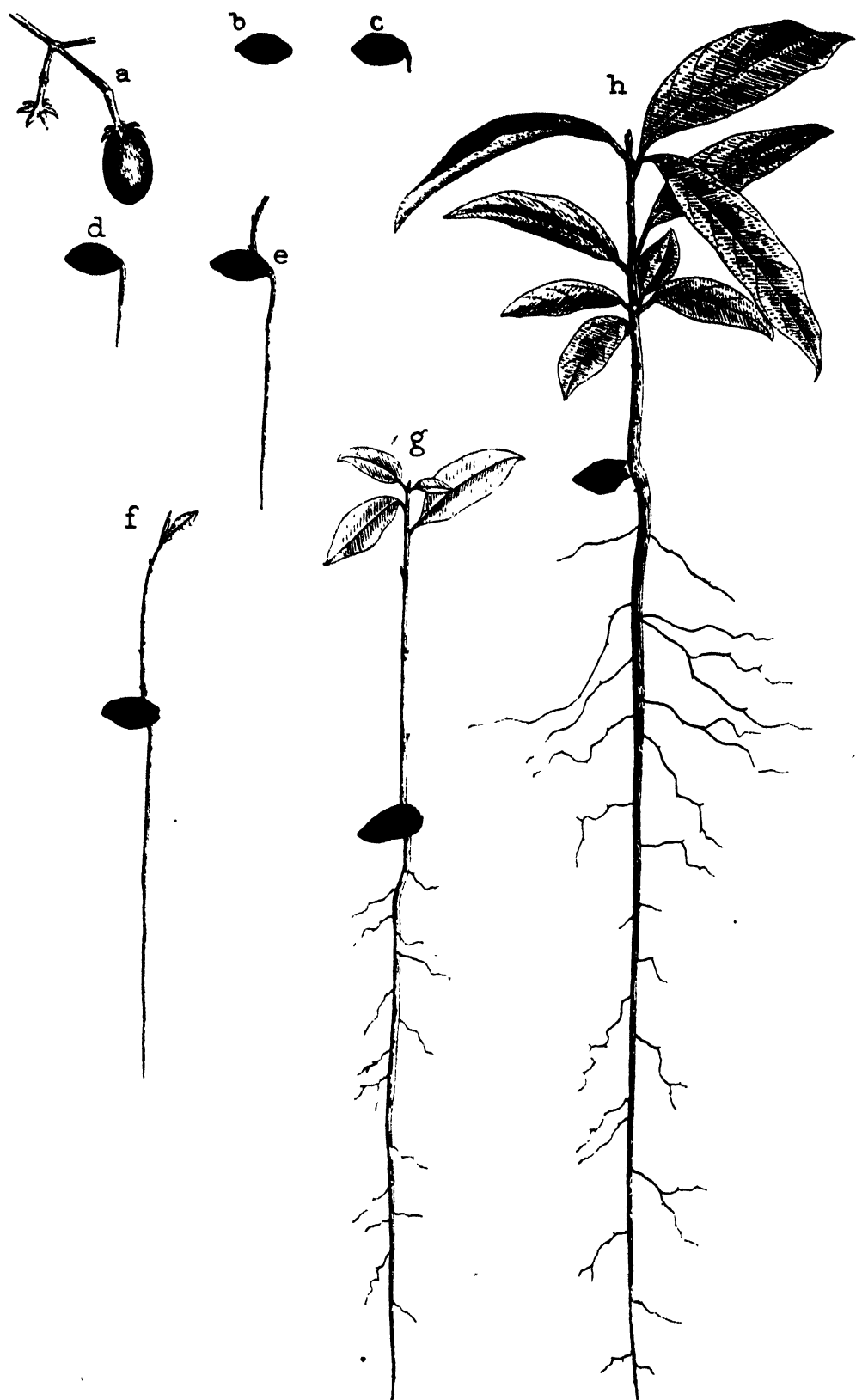


FIG. 298. *Machilus odoratissima*. Seedling $\times \frac{1}{2}$.
 a, fruit ; b, seed ; c-e, germination stages ; f-h, development of seedling to end of first season.

and may be collected off the ground in quantity. The seeds (Fig. 298, *b*) are 0.4 in. long; about 80–100 weigh 1 oz. They do not retain their vitality long.

GERMINATION (Fig. 298, *c–e*). Hypogeous. The radicle first emerges from one end of the seed, and then the young shoot breaks through the testa and emerges from the upper side of the seed. The cotyledons are left within the testa on or under the ground.

THE SEEDLING (Fig. 298).

Roots : primary root moderately long and thick, terete, tapering, woody, dark brown; lateral roots numerous, moderately long, fibrous. *Hypocotyl* indistinguishable. *Cotyledons* sessile, 0.4–0.5 in. by 0.25 in., thick, fleshy, elliptical, outer surface rounded, smooth, inner flat. *Stem* erect, terete or slightly compressed, wiry, green, or young parts often red, glabrous; internodes 0.1–1.5 in. long. *Leaves* alternate, sometimes sub-opposite, exstipulate, first few leaves often rudimentary and scale-like. *Petiole* 0.25–0.5 in. long, channelled above, green or red, glabrous. *Lamina* 0.9–4 in. by 0.5–1.1 in., oblong lanceolate, acuminate, entire, glabrous, dark green and shining above, slightly glaucous beneath, venation arcuate reticulate, lateral veins 6–8 pairs, midrib sometimes red.

The growth of the seedling is somewhat slow, the height ordinarily attained being about 3 or 4 in. by the end of the first and 9 or 10 in. by the end of the second season. Subsequently the growth is faster; young plants raised at Dehra Dun reached a height of 5 ft. by the end of the fourth season. Seedlings require moisture and a certain amount of shade for their best development, and are sensitive to drought.

SILVICULTURAL CHARACTERS. The tree is a shade-bearer, especially in youth, but later it is apt to become suppressed if the cover is dense. It is, however, fairly hardy, and will thrive without shade; it grows best in moist situations. It is not browsed by cattle.

NATURAL REPRODUCTION. Under natural conditions germination takes place early in the rainy season, not long after the fall of the fruit. Experiments carried out at Dehra Dun showed that shade, probably from its effect in producing the necessary moisture conditions, is a factor favourable to successful reproduction. Bare ground and loose soil in which the seed becomes quickly buried by rain are also favourable, while weed-growth is an adverse factor. Seedlings often appear in large quantities near seed-bearers in the shade of the forest, particularly where the ground has been cleared or the soil worked, as along newly-made paths. The admission of moderate light stimulates the development of natural seedlings.

ARTIFICIAL REPRODUCTION. Fresh seed should be sown in the nursery soon after the fruits ripen, in June–July, and lightly covered. The beds should be kept shaded and regularly watered. The seedlings usually commence to appear in about three weeks, and may be transplanted at the beginning of the rainy season when one or two years old. They stand transplanting well. This is a useful tree for underplanting purposes under moderate shade.

RATE OF GROWTH. A cross-section in the silvicultural museum at Dehra Dun showed 31 rings for a girth of 2 ft. 4 in., giving a mean annual girth increment of 0.9 in.

2. *Machilus Duthiei*, King. Vern. *Kawla*, Hind. ; *Bhojo*, Jaunsar.

A shady evergreen tree, larger than *M. odoratissima*, and with leaves 5–10 in. long, very coriaceous, glaucous beneath. Western Himalaya, in ravines and shady places, at 4,000–8,000 ft., usually at higher elevations than *M. odoratissima*, but resembling it more or less in requirements. Flowers April–May; fruits June–July. The fruit is globose, about 0·5 in. in diameter. Growth slow (Gamble).

3. *Machilus Gamblei*, King. Vern. *Kawla*, Nep.

The low-level *Machilus* of the outer Himalaya and sub-Himalayan tract, at 2,000–4,000 ft. along ravines and streams, and in moist shady places. In the Dehra Dun valley it is a characteristic swamp species. Leaves 3–5 in. long, thinly coriaceous. Flowers March–April; fruits June–July. Fruit globose, black, 0·3 in. in diameter.

4. *Machilus edulis*, King. Vern. *Lepcha phal*, Nep.

A large evergreen tree of the eastern Himalaya at 4,000–8,000 ft. An important tree in the Darjeeling forests. Leaves 5–12 in. long, narrow, thickly coriaceous. Fruit 1·5 in. in diameter, edible. The tree reproduces well; the seedlings are frost-tender, and suffered much in the abnormal frost of 1905. The wood is used for planking, tea-boxes, &c. Growth, according to Gamble, 5 to 9 rings per inch of radius, giving a mean annual girth increment of 0·7 to 1·26 in.

5. *Machilus bombycina*, King. *Soom*, Ass. ; *Kawla*, Duars.

A moderate-sized tree with elliptical lanceolate leaves, 4–5 in. long. The bark, especially on the lower part of the stem, is often covered with warty excrescences somewhat resembling small potatoes, and having the same colour and consistency; these later turn black and dry up. This tree is the principal one on which the *muga* silkworm is raised in Assam. It is common in the Bengal Duars and in parts of Assam, especially in the Sibsagar district, and is frequently cultivated and has run wild. In the Buxa Duars it forms pure forests on damp clayey flat localities or is mixed with sal and other species. On old savannah lands which have been brought under fire-protection, it springs up freely and gregariously on moist low-lying places, eventually killing out the grass. In the forest also it regenerates with great freedom, seedlings being found in large quantities; they somewhat resemble seedlings of *Eugenia Jambolana*, except that they have alternate instead of opposite leaves. The tree coppices well. The panicles of small flowers appear about March, and the fruits ripen at the commencement of the rainy season. The fruit is about 0·3 in. in diameter.

3. PHOEBE, Nees.

Seven Indian species of evergreen shrubs and trees.

Species 1. *P. lanceolata*, Nees ; 2. *P. attenuata*, Nees.

1. *Phoebe lanceolata*, Nees. Vern. *Bhadroi*, Jaunsar ; *Tumri*, Dehra Dun ; *Kat kawla*, Kumaun.

A small or moderate-sized evergreen tree with narrow coriaceous leaves 5–8 in. long crowded at the ends of the branches. Bark yellowish white. Sub-Himalayan tract and outer valleys, ascending to 6,500 ft., Khasi hills,

Chittagong, Upper Burma, hills of southern India. A shade-bearing species found chiefly in moist shady ravines and near swamps (e. g. in the Dehra Dun valley). Flowers February–June; fruits June–September. The fruit is 0.3–0.4 in. long, ellipsoidal, black when ripe. Growth, according to Gamble, 3 to 4 rings per inch of radius, giving a mean annual girth increment of 1.57 to 2.1 in., which is fast.

2. *Phoebe attenuata*, Nees. Vern. *Lepcha kawla*, *angaria*, Nep.; *Hlega*, *thitya-wa*, Burm.

A large evergreen tree of the eastern Himalaya, ascending to 4,000 ft., Assam and Upper Burma. Manson (Darjeeling working plan) says that it germinates profusely even under low cover provided the ground is fairly clear of weeds, that the fruit is eaten by bears, and that at low elevations it is a good tree to plant amidst scrub.

4. CINNAMOMUM, Blume.

About 20 or perhaps more Indian species of evergreen trees and shrubs. Two are of special economic importance, *C. zeylanicum*, Breyn, the cinnamon tree, indigenous, and *C. Camphora*, Nees, the camphor tree, introduced.

Species 1. *C. Tamala*, Nees; 2. *C. Cecidodaphne*, Meissn.; 3. *C. zeylanicum*, Breyn; 4. *C. Camphora*, Nees.

1. *Cinnamomum Tamala*, Nees. *Cassia cinnamon*. Vern. *Dalchini*, Hind.; *Thitchabo*, Burm.

A moderate-sized handsome evergreen tree with shining 3-nerved aromatic leaves. Bark thin, dark brown, wrinkled, aromatic. The leaves (vern. *tezpat*) are used in medicine and for flavouring purposes; the bark, which is known as 'cassia bark', is used in medicine and as a substitute for true cinnamon. Sub-Himalayan tract and outer ranges, ascending to 7,000 ft., but commonest at 3,000–5,000 ft.; rare west of the Sutlej; Assam, Upper Burma. A shade-bearing species frequenting moist ravines. The young leaves, which are pink, appear in April or May. The panicles of yellowish white flowers appear from February to May, and the fruit, a black ovoid drupe 0.5 in. long, ripens from June to August. Growth, according to Gamble, 6 to 10 rings per inch of radius, giving a mean annual girth increment of 0.63 to 1.05 in.

2. *Cinnamomum Cecidodaphne*, Meissn.

A tall handsome evergreen tree of the eastern sub-Himalayan tract, ascending to 4,000 ft., Assam and Manipur. A clump of trees is growing well in the Kaunli garden, Dehra Dun, and trees felled have coppiced vigorously. These trees seed freely at intervals of two or three years, in October–November, the fruits falling from November to January; hitherto efforts to raise plants from Dehra Dun seed have failed, the seed possibly being infertile. The flesh of the drupes is very fragrant.

3. *Cinnamomum zeylanicum*, Breyn. *Cinnamon tree*. Vern. *Dalchini*, Kan.; *Karuva*, Tam.; *Hmanthin*, Burm.

A moderate-sized to large very variable evergreen tree with thickly coriaceous 3- or 5-veined leaves, shining above, dull beneath. Old bark rough, brown; young bark smooth, pale coloured. The bark and leaves are very

aromatic, the former yielding the cinnamon of commerce and the latter being used for flavouring.

The tree is indigenous to the Western Ghats and adjoining hill ranges from the Konkan southwards, ascending to 6,000 ft. ; very common in North Kanara. Also in Tenasserim and the moist low country of Ceylon. In Ceylon the tree is extensively cultivated in gardens and worked under a system of coppice selection, which is thus described by Brandis :¹

‘ According to Leschenault de la Tour, *Mémoires du Muséum d’histoire naturelle*, viii (1822), 436, and notes on the subject collected during a late visit to Ceylon, which I owe to the kindness of Dr. George King, the Cinnamon tree in Ceylon is generally grown in irregular coppice-woods, pure or mixed with other shrubs. Some of the stools are of great age and girth, and are said to have been planted by the Dutch when they held the island. The formation of fresh Cinnamon coppice is thus described by Leschenault de la Tour : The tree flowers more or less throughout the year, but most abundantly in January, February, and the fruit ripens from June to August. The seeds, which are oily, do not long retain their vitality ; they are sown soon after ripening, either in nurseries to be transplanted in October or November, or on the spot in plots about 1 ft. square and 6–7 ft. apart. The plants attain 7–8 ft. in 6–7 years, and those which are then fit to be peeled are cut, and the shoots which spring up are thinned out when they are 2, 3, or 4 years old, or even at an earlier age. They are not cut when less than $\frac{1}{2}$ in., or more than $2\frac{1}{2}$ in. diam. The whole growing crop in one plot is never cut over at once, as would, for instance, be done in a regularly managed Oak coppice-wood, but those shoots only are selected which appear fit to be used, and are in such a state as to be peeled readily. The main point attended to seems to be, to cut the shoots when quite young and tender ; it is said that the bark of the older shoots yields inferior Cinnamon (G. King). The cutting is done during the rainy season, between May and October ; the bark is peeled off after cutting in three or four long narrow strips from each shoot ; it is then tied tightly together in parcels, and left for twenty-four hours. At the end of this time the epidermis and the outer bark are removed, and the inner bark, which is the aromatic and valuable part, is dried, the first day in the shade, the second day in the sun, when it gradually rolls up, forming the quills of Cinnamon, which are placed into each other and tied in bundles. The fruit of the Cinnamon tree is eaten greedily by crows, pigeons, and other birds ; the seeds pass uninjured, and thus the spread and preservation of the tree is secured apart from the planted coppice-woods. Indeed, formerly almost all Cinnamon brought to market was from naturally-grown trees ; and to enable their Cinnamon collectors to enter the forests beyond the limits of their own possessions, the Dutch concluded a treaty with the King of Candy, and it is said that planting was only resorted to when the supply from natural sources had become deficient.’

In North Kanara the right of collecting cinanmon bark from wild trees is sold, but the revenue received is not large, the bark obtained being inferior in quality to that grown in Ceylon. In the Western Ghats the tree grows on any soil, but perhaps best on laterite (Foulkes). Flowers November–February ; fruits June–July (Talbot). The fruit is a dark purple one-seeded ellipsoidal berry 0.5–1 in. long.

4. *Cinnamomum Camphora*, Nees. Syn. *Camphora officinarum*, Bauh. Japan or Formosa camphor tree.

A large handsome evergreen tree, attaining in its natural habitat a height

¹ For. Fl. : North-West and Central India, p. 375.

of 100 ft. and a girth of 6 to 8 ft. or more, but in India often rather stunted if grown in unfavourable situations. Leaves coriaceous, shining, 2-4 in. long, smelling strongly of camphor when crushed. Bark brown, rough when old. When grown in an open position the tree tends to branch low, forming a short thick bole, massive branches, and a dense rounded crown. When grown in a dense crop, however, the trees form comparatively straight clean boles (Fig. 299). Apart from its economic value, the tree is an excellent one as an avenue tree and as an ornamental and shade tree in parks and gardens. It has been found at Dehra Dun, however, that other plants do not grow well in its vicinity; whether this is due to the fact that the roots tend to spread near the surface or to some toxic influence, is not certain. The wood is moderately hard, somewhat rough, strongly scented with camphor, and used mainly for cabinet-making. The chief product of the tree, however, is camphor, used largely in the manufacture of celluloid and smokeless powders and also to some extent as a drug and insectifuge. Camphor oil is obtained from the camphor by separation; it is used in soap manufacture and for other purposes. In the normal times preceding the outbreak of war in 1914 the world's consumption of camphor was about 11,000,000 lb. annually, the price on the London market varying from 1s. 4½d. to 3s. 6d. per lb. Almost the whole outturn of camphor is obtained from Japan, Formosa, and China; the trade in camphor from Japan and Formosa is practically a Japanese Government monopoly, and about 70 per cent. of the world's output within recent years has been obtained from Japanese sources. The manufacture of synthetic camphor was commenced a few years ago by several factories, but the process proved too expensive, while the camphor produced had not the requisite properties and proved too highly inflammable. The high prices obtained for camphor within recent years have led to efforts being made in various parts of the world to form plantations of this tree for profit, and in suitable localities the prospects are distinctly good.

Camphor can be distilled from all parts of the tree, from chips of wood from the stem, branches and roots, as well as from the twigs and leaves; it has even been distilled from the fallen leaves. As the method of growing the tree must depend on a decision as to whether the principal yield is to be obtained from the wood or from the leaves and twigs it is of importance to know the probable outturn of camphor from different parts of the tree. This appears to vary largely in different localities, as is shown in the summary of tests quoted below. In the natural forests of Formosa the camphor is obtained by distilling chips of the wood, since the trees are already of comparatively large size, while the yield of camphor from Formosan wood appears to be much higher than in the case of wood samples tested from trees grown in other parts of the world. For plantation purposes it is recognized that the yield can be most profitably obtained from the leaves and twigs, and the plants are grown in bush-like form accordingly.

A description of the processes of distillation is beyond the scope of this work. The old Japanese methods are crude. Improved methods of steam distillation with various types of stills have been carried out by different investigators from time to time. Among others the apparatus designed by Mr. Puran Singh and described on p. 273 of my *Indian Forest Utilization*,

2nd edition, 1913, has been found to work satisfactorily ; in this apparatus the oil is separated from the camphor by a centrifugal machine. A useful account of distillation and condensation methods is given in a note entitled *Camphor Cultivation in the United States*, by S. C. Wood and R. H. True,¹ as also in a note entitled *Camphor from Cinnamomum Camphora*, by B. J. Eaton.²

DISTRIBUTION AND HABITAT. The natural habitat of the tree is in eastern Asia from Cochin China to Shanghai and in the islands from Hainan to southern Japan, that is between 10° and 34° N. lat. The most extensive camphor forests are those of Formosa, which are situated chiefly in the northern portion of the island : the climate of this island is moist and tropical to sub-tropical, the vegetation being rich and varied and containing some trees of the Indian region, such as *Bombax malabaricum*, *Bischofia javanica*, *Calophyllum Inophyllum*, and *Terminalia Catappa*.

The tree has been cultivated more or less successfully in many parts of the world, including India, Burma, Ceylon, the Malay States, Java, Australia, East and South Africa, Italy, Algiers, Florida, California, Brazil, the West Indies, Mauritius, and Madeira. This indicates that it is capable of growing in a wide range of climates throughout the tropical and warm temperate parts of the globe. It was introduced into Ceylon in 1852, and grows at all elevations from sea-level up to the highest elevations provided the soil and climate are suitable, but probably thrives best below 5,000 ft. ; generally speaking it has done best where the rainfall is 90 in. or over.

In India it has been grown successfully in a number of localities. There are fine trees at Dehra Dun, for instance the camphor avenue at the Forest Research Institute, and in the Botanic Gardens at Saharanpur and Calcutta ; the latter gardens possess a fine avenue of camphor trees introduced in 1802. In the Nilgiris it does well even up to 7,000 ft. It has been grown successfully in many parts of Burma. It does very well at Maymyo, 3,500 ft. : in the Bhamo district it thrives up to 3,000 ft., but at high elevations it does not endure the cold well. In the Southern Shan States it has not been very successful at Taunggyi, 4,700 ft. ; it has done better at Kalaw, 4,300 ft., and better still at Lawksawk, 3,000 ft., where the growth is said to be very rapid. In India and Burma generally speaking it seems to do best at low to moderate elevations where the rainfall is about 60 in. and over, though it grows fairly well even where the rainfall is under 50 in., as at Saharanpur.

For its best growth the tree requires a deep well-drained fertile sandy loam and a sheltered situation. It will not thrive on stiff badly drained soils. Eaton states that it appears to thrive in the Federated Malay States on comparatively poor laterite soil provided it is well drained and not swampy. On poor ground the growth is usually stunted.

LEAF-SHEDDING, FLOWERING, AND FRUITING. In northern India the leaves are shed about February–March, and the new leaves appear in February while the old ones are falling. In March–April the trees are covered with masses of pale green fragrant flowers. The fruits ripen in October. The fruit is a dark green, rather dry, globose, one-seeded berry, about 0.3 in. in diameter,

¹ U.S.A. Yearbook, Dept. of Agriculture, 1910.

² Federated Malay States, Dept. of Agric., Bull. No. 15, 1912.

turning black after ripening ; it should not be collected until it has turned a dull black colour. The seed is very oily, and retains its vitality only a few months. According to Nock,¹ about 5,600 seeds weigh 1 lb. In the case of samples collected at Dehra Dun 2,100 to 3,200 of the fruits weigh 1 lb. Good seed if cut open is white inside ; if it is brown or black it may be regarded as useless.

In Japan the seed ripens in October–November, and in order to obtain it in fresh condition orders should be timed to reach that country not later than September. Packing in damp charcoal is said to preserve the fertility of the seed better than any other method. Fertile seed can, however, be procured to a limited extent in India. Some of the trees grown at Dehra Dun seed freely, but not every year. In Japan the tree is said to commence producing seed at the age of 20–25 years. Trees 17 years of age have been observed in flower at Dehra Dun, but the seed from these has not been tested.

SILVICULTURAL CHARACTERS. The tree stands a fair amount of shade, but develops best with a liberal supply of light. It coppices vigorously, the shoots growing rapidly ; coppice-shoots persist well under shade, as shown in a plantation at Dehra Dun where the stools of trees removed in thinnings all sent up coppice-shoots, but the shoots round the edge of the plantation, where they received plentiful light, grew far more vigorously than those under shade in the interior of the plantation. The tree also produces root-suckers. It stands repeated pruning, and can be trimmed down to the form of a bush or hedge. Large trees at Dehra Dun sometimes become dry-topped, sending out masses of shoots at the base in token of bad condition, while the smaller branches sometimes fall off, leaving cankerous hollows in the stem and main branches. In America the tree has been found to be hardy where the temperature does not fall below 15° F., though even at this temperature unligified twigs may be killed by frost.

ARTIFICIAL PROPAGATION AND CULTIVATION. The camphor tree can be raised from seed, layers, branch-cuttings or root-cuttings, or by transplanting root-suckers. The first method is the most satisfactory for plantation purposes. Layering is fairly successful but slow ; the method found most satisfactory in Ceylon is that known as tonguing or heeling ; the branch at the lowest point of the bend where it will be under the soil being cut half-way through on the under side below a bud and slit upwards for a short distance. Branch-cuttings do not as a rule prove successful, a very small proportion surviving. Root-cuttings about 2½ in. or more in length, provided they possess good buds, have proved very successful. The best results in Ceylon have been attained by inserting the cutting more or less vertically in such a position as to bring its upper cut surface (which should be that nearest the stem of the plant) near the surface of the ground. Nock estimates that 75 to 100 good root-cuttings could be obtained from a tree eight to ten years old without harmful results.

For raising plants from seed, fresh seed should be sown in the nursery during late winter. At Dehra Dun sowing in boxes has proved more successful

¹ Propagation of Camphor, J. K. Nock, *Cir. and Agric. Journ. Roy. Bot. Gardens, Ceylon*, vol. iv, No. 3, May 1907.

than sowing in seed-beds, but in either case a well-worked porous soil is necessary, this consisting preferably of an equal mixture of loam, sifted leaf-mould, and pure sand, all well mixed and pulverized. It is sometimes customary to soak the seeds in water for twenty-four hours before sowing, those which sink being sown about $1\frac{1}{2}$ in. apart, and those which float, and of which very few will be fertile, being sown thickly. The soil should be watered before sowing and the seeds covered to a depth of about half an inch, the beds or boxes being shaded; drip should, however, be avoided. Germination may take some months, and in order to prevent the seed rotting in the meantime, water should be given sparingly though regularly. During the first rainy season the plants should be pricked out in the nursery with a spacing of about 6 in. by 8 in., or into baskets. They will be ready to plant out during the second rainy season, but as a long taproot is often developed it may be necessary to trim it down and to prune down the stem; the plant stands this treatment.

For camphor distillation plantations are formed with the object of producing crops of leaves and small twigs, and are trimmed into bush or hedge form for the purpose. The best spacing for Indian requirements has not yet been ascertained, but probably one of 6 ft. by 6 ft. to 8 ft. by 8 ft. will be found suitable. In America a spacing of 6 ft. by 15 ft. has been tried; this seems unnecessarily wide, but was adopted to facilitate cultivation. The ground should be well tilled and harrowed before planting, and dug up periodically. The first harvest of leaves is obtained when the plants have produced thick woody stems, that is, ordinarily in about five years, or under favourable conditions less. They are then trimmed to bush-like form and a size convenient for easy working; the number of flushes of leaves and twigs obtainable will probably be found to vary locally. Estimates of the yield from plantations are given below.

RATE OF GROWTH. Under favourable conditions the rate of growth is rapid, but on poor soils it is slow. In the natural habitat of the tree a height of 30 ft. and a diameter of 6 in. in ten years is said to be good growth. According to Gamble some Dehra Dun specimens showed nearly 1 ring per inch of radius, that is, a mean annual girth increment of about 6 in., which is very rapid. Cross-sections of three trees grown at Dehra Dun showed the following growth:

1. Girth 5 ft. 10 in.; rings 31; mean annual girth increment 2.26 in.
2. Girth 3 ft. 4 in.; rings 23; mean annual girth increment 1.74 in.
3. Girth 1 ft. 10 in.; rings 17; mean annual girth increment 1.30 in.

The third specimen was from a close-grown plantation. In Ceylon under favourable conditions the tree attains a height of 18–20 ft. and a diameter of 6–7 in. in five years (Nock). According to Hood and True, experiments were made in the United States in coppicing trees six to ten years old, and in all cases the coppice-shoots made a growth of 6 to 10 ft. in the first year.

A plantation formed in 1898 in the Kaunli garden, Dehra Dun, was thinned in 1915 and again in 1917. The following measurements were recorded after each thinning:

Cinnamomum Camphora : measurements in Kaunli plantation, Dehra Dun.

Year of measurement.	Age.	No. of stems per acre.	Mean girth.	Mean height.	Solid volume per acre.	Intermediate yields from thinnings.
						Solid volume.
			ft. in.	ft.	cub. ft.	cub. ft.
1915	17	561	1 5.5	53	2,366	885
1917	19	383	1 9.2	54	2,317	648

Fig. 299 shows the appearance of the plantation after the first thinning.

YIELD. According to the results of analyses carried out by various investigators in different parts of the world, the yield of camphor from the wood, branches, twigs, and leaves varies greatly under different conditions. Formosan wood is generally reported to yield 3-4 per cent. of camphor, but this has not been nearly equalled by tests carried out in other countries ; in Formosa, however, the trees in question are probably much older than those experimented with elsewhere. The statement on page 796 gives the results of tests recorded by different investigators.

Accurate estimates of the yield per acre from trimmings of leaves and young twigs of plants grown as bushes have not yet been made, but the following rough estimates may be quoted :

1. Bamber and Willis estimate that 12 to 15 lb. of clippings a year may be expected ; this yield has been exceeded in the Hakgala Gardens, Ceylon, so far as rough experiments show. With a spacing of 6 ft. by 6 ft. or 1,210 plants per acre this will give a yield of 14,000 to 18,000 lb. of clippings per acre, or 140 to 180 lb. of camphor per acre per annum at 1 per cent.

2. Eaton estimates that in the Federated Malay States an acre of camphor three years old, planted 8 ft. by 8 ft., that is 700 plants per acre, should yield about 60 lb. of camphor from one pruning or 180 lb. per annum in three prunings.

3. Hood and True estimate that in the United States bushes spaced 6 ft. by 15 ft. and grown 8 ft. high will give 8,000 lb. of trimmings per acre for each of two cuttings, making a total of 8 tons per acre per annum, and yielding 175 to 200 lb. of marketable camphor per acre.

These three estimates, it will be seen, are very near each other. It is of interest to note that Hood and True consider that 200 acres is the minimum planted area which would warrant the erection of a distilling and refining plant, and that 500 acres would probably ensure the minimum cost of production of marketable camphor.

5. LITSAEA, Lam.

A large genus containing nearly 50 species of evergreen or deciduous trees, none of any great importance. The flowers are dioecious, in small umbellate heads.

Species 1. *L. sebifera*, Pers. ; 2. *L. polyantha*, Juss.

1. *Litsaea sebifera*, Pers. Syn. *L. chinensis*, Lam. ; *Tetranthera laurifolia*, Roxb. ; *T. apetala*, Roxb. Vern. *Maida lakri*, Hind. ; *Elumpurukki*, Tam. ; *Ondón*, Burm.

A moderate-sized very variable evergreen tree with slightly aromatic

Cinnamomum Camphora : recorded tests giving yield of camphor.

Locality.	Investigator.	Wood.	Percentage of crude distillate from different parts of tree.			Leaves.	Remarks.
			Branches and twigs.	Young shoots.	Leaves and twigs.		
India							
Nilgiris	Hooper ¹					1.0	Yield of camphor 10-15 per cent. of distillate from tree at Ootacamund and 75 per cent. from tree at Naduvattam.
Dehra Dun	Puran Singh ²	Stem 0.66 [0.97]	{ Large branches 0.46 [0.51] Small branches 0.21 [0.25]	0.27 [0.31]		0.24 [0.42]	Figures in square brackets show percentage of dry camphor calculated on <i>dry</i> material.
Ammayanayakanur (Madras)	Puran Singh ²					[1.79]	Figures in square brackets show percentage of dry camphor calculated on <i>dry</i> material.
Cochin State	Puran Singh ²						Figures in square brackets show percentage of dry camphor calculated on <i>dry</i> material. Camphor oil 0.29 per cent.
Abroad							
Ceylon	Willis and Bamber ³	No appreciable quantity from wood of branches and stem			Average 0.75-1 per cent. of camphor and a small quantity of camphor oil	1.10-1.54 1.0	
Malay States	Eaton ⁴			0.06-0.45	1.25 and 1.58		
East Africa	Lommel ⁵			0.22			
West Indies	Watts and Tempany ⁵	0.5	0.06-0.1		0.5 and 1.7		
Italy	Giglioli ⁵						
U.S.A.	Hood and True ⁶			0.02 and 0.25			{ Green 1.2-1.5 { Dried 2.4-3.0 Fallen dead leaves 0.2
Jamaica	Kennedy and Duncan ⁷	0.61		0.05			{ Green 2.37 { Dried 2.52 { Dead 1.39

¹ Ind. Forester, xxii (1896), p. 111.

⁴ F.M.S., Dept. of Agric., Bull. No. 15, 1912.

² Ibid., xli (1915), p. 291.
Quoted by Eaton, loc. cit.

Quoted by Eaton, loc. cit.

³ Cir. Roy. Bot. Gardens, Ceylon, Series I, No. 24, Nov. 1901.
⁴ U.S.A. Yearbook, Dept. of Agric., 1910. ⁵ Harper's Magazine, Feb. 1911.

³ Cir. Roy. Bot. Gardens, Ceylon, Series I, No. 24, Nov. 1901.
Cook, Dept. of Agric., 1910. ⁷ Harper's Magazine, Feb. 1911.

7 Harper's Magazine, Feb. 1911.

leaves and grey smooth corky bark, viscous inside. Wood moderately hard, fairly durable and of good quality. Widely distributed throughout India and Burma, but nowhere very abundant; usually in valleys and fairly moist places. In the sub-Himalayan tract it is common in sal forest. In northern India the old leaves fall from December to February, often turning greyish brown or yellow, mottled with green and bluish black spots. The new leaves appear before the old ones have all fallen. The flowers appear in the rainy season, and the fruits ripen in the following cold season; the fruit is a black globose drupe about 0.3 in. in diameter. The tree stands a fair amount of shade and coppices well. Gamble gives the rate of growth as 6.7 rings per inch of radius, representing a mean annual girth increment of about 0.94 in. A cross-section in the silvicultural museum at Dehra Dun showed 51 rings for a girth of 3 ft. 9 in., giving a mean annual girth increment of 0.88 in. Two trees measured for a period of twelve years in a sample plot in the Siwalik tract showed a mean annual girth increment of 1.01 in. for the period. Coppice growth, for some years at least, is usually fast. Measurements in 1910 by Mr. C. M. McCrie in coppice coupes in the Gorakhpur district, United Provinces, and in 1886 by Mr. A. F. Broun in the Bullawala coppice near Dehra Dun, gave the following results for *Litsaea sebifera* as compared with sal:

Litsaea sebifera: coppice measurements, United Provinces.

Age. years.	Gorakhpur.		Bullawala (Dehra Dun).			
	Mean height.		Mean height.		Mean girth.	
	<i>Litsaea</i> . ft.	Sal. ft.	<i>Litsaea</i> . ft.	Sal. ft.	<i>Litsaea</i> . in.	Sal. in.
2	6.5	3.0	..	..	..	..
4	9.4	7.0	..	..	..	..
6	12.0	10.3	..	..	..	..
8	14.1	13.0	18.3	13.2	6.9	7.1
9	..	..	(1) 12.5	16.0	8.4	8.6
..	..	..	(2) 16.6	13.5	13.2	8.7
10	15.4	15.3	18.4	11.9	11.0	5.9
12	17.0	17.5	..	..	..	..
14	18.3	19.2	..	..	..	..
16	19.0	20.9	..	..	..	..

In the Gorakhpur measurements the mean girth in a coupe sixteen years old was 9.7 in. for *Litsaea* as compared with 6 in. for sal.

Measurements in young coppice coupes in the Tikri forest, Gonda, United Provinces, showed slower growth, namely:

Age 1 year: mean height, *Litsaea* 4 ft., sal 4.7 ft.

Age 2 years: mean height, *Litsaea* 4.3 ft., sal 7.6 ft.

2. *Litsaea polyantha*, Juss. Syn. *Tetranthera monopetala*, Roxb. Vern. *Katmarra*, *meda*, *singran*, *karkāwa*, Hind.; *Ondôn*, Burm.

A small to large tree, evergreen or nearly so, with a large spreading crown. Bark dark grey, smooth. Common in the sub-Himalayan tract, usually in scrub forests; also in Bengal, Assam, the Central Provinces (chiefly along streams), the Circars and Burma (common in the plains forests). The tree is often planted for ornament. In northern India the leaves are shed in March and April, at which time also the flowers appear chiefly on the upper leafless branches while the lower branches are still in leaf. The fruit, a drupe 0.2–

0·4 in. long, ripens in the rainy season. Growth, according to Gamble, 2 to 6 rings per inch of radius, giving a mean annual girth increment of 1·05 to 3·14 in., which is fast. A tree measured for a period of four years in a sample plot in the Siwalik tract showed a mean annual girth increment of 0·59 in. for the period.

ORDER XLVIII. PROTEACEAE

This order is represented chiefly in Australia and South Africa, and contains only one Indian genus, *Helicia*, Lour. The only tree which is of special interest in India is the Australian tree *Grevillea robusta*, A. Cunn.

GREVILLEA, R. Br.

***Grevillea robusta*, A. Cunn.** Silky oak.

A moderate-sized evergreen tree with a long conical crown, a definite leader, and deeply pinnatifid leaves. Bark dark grey, rough. A native of Australia (Queensland and New South Wales), it is often planted in suitable localities in India. In the Nilgiris it grows well at moderate elevations, chiefly at 4,000–6,000 ft., and is used as a shade tree in coffee plantations. It does well at Dehra Dun, at Maymyo in Burma, and generally at moderate elevations where there is a fair rainfall. It grows very rapidly, and is a graceful tree up to an age of about fifteen to twenty years, after which it often becomes ragged and unsightly. It makes an excellent temporary avenue tree, growing up quickly while some slower growing but more enduring species grown with it is ready to take its place. It is not particular as to soil, and is easily raised in the nursery, standing transplanting well. It is somewhat brittle and liable to be broken by wind in exposed places. In India natural seedlings are often found; they come up readily through hedges and bushes where they obtain protection. The tree flowers from March to May, when masses of golden-yellow flowers cover the branches in flat horizontal tiers. The fruit is a small 1- or 2-seeded follicle; about 3,000 seeds weigh 1 oz.

ORDER XLIX. THYMELAEACEAE

AQUILARIA, Lam.

***Aquilaria Agallocha*, Roxb.** Eaglewood. Vern. *Agar*, Beng.; *Sasi*, Ass.; *Akyaw*, Burm.

A tall evergreen tree of the eastern Himalaya, Assam, eastern Bengal, and Burma, especially in Tenasserim. It furnishes the eaglewood or agarwood of commerce, occurring in the form of dark-coloured resinous fragrant masses in the centre of the bole; these are used for burning as incense, while the light-coloured wood in which the masses are embedded is distilled into an oil called *agar-attar*, which is used as a perfume. The tree is said to regenerate freely. An experimental plantation of it has been in existence for some years in the Sibsagar district of Assam; the plants are reported to have suffered from the ravages of wild elephants.

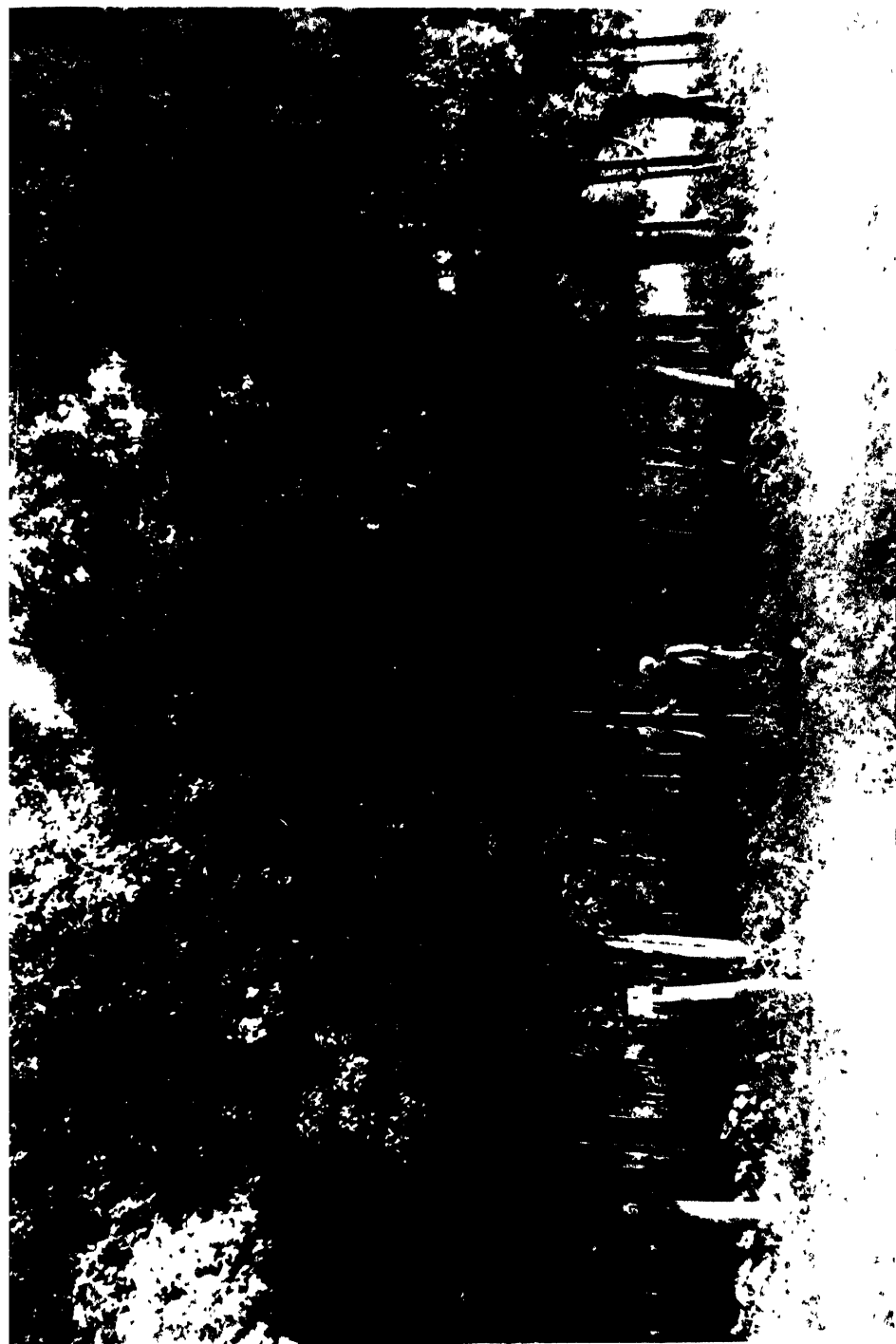


FIG 299 *Cinnamomum Camphora*, plantation 17 years old at Kauli, Dehra Dun



FIG. 300. *Santalum album*, a well-grown young tree.



FIG. 301. *Santalum album*, normal leaves on left, and spiked leaves on right.

ORDER L. LORANTHACEAE

This order consists of evergreen parasitic shrubs which are of importance owing to the damage they do to trees. They obtain nourishment from their hosts by means of haustoria which penetrate into the tissues of the hosts ; as they possess green leaves they are able to carry out the process of assimilation. A severe attack of loranthaceous parasites may kill the host, and when the host dies the parasite itself in turn dies. The commonest Indian species is *Loranthus longiflorus*, Desr., a widely distributed species with a large variety of host plants, even *Pinus longifolia* being subject to its attacks. It does much damage to mango trees, and it is probably the chief species responsible for the extensive injury done to *mohwa* (*Bassia latifolia*) trees in the Indian Peninsula, where it is a serious menace and the cause of much mortality. *L. vestitus*, Wall., is a common species on the oaks of the western Himalaya. *Viscum album*, Linn., the mistletoe, is found in the Himalaya and other hill ranges and attacks fruit trees as well as poplar, willow, and other trees. *Arceuthobium minutissimum*, Hook. f., is a minute parasite which damages *Pinus excelsa* in the western Himalaya. It can be detected from the small warty excrescences which it produces on the twigs of the pine, the injury somewhat resembling that of an insect attack.

Perhaps the only method of keeping loranthaceous parasites in check is by removing them systematically or lopping off affected branches : where the hosts are deciduous trees, this can best be done when they are leafless, the evergreen parasites showing up conspicuously. The seeds appear to be spread for the most part by birds.

ORDER LI. SANTALACEAE

An order of trees, shrubs, and herbaceous plants, mostly root-parasites, but some parasitic on the stems and branches of their hosts. The only Indian tree of special importance is *Santalum album*, Linn.

SANTALUM, Linn.

Santalum album, Linn. Sandalwood. *Chandana*, Sans. Vern. *Chandan*, *chandal*, *sandal*, Hind. ; *Gandada*, *gandha*, Kan. ; *Suket*, Guz. ; *Chandanam*, Tel. ; *Santhanam*, *srigandam*, Tam. ; *Chandana*, Coorg ; *Santagu*, Burm. (Fig. 300.)

A small evergreen glabrous tree with slender drooping branchlets. Leaves opposite, sometimes alternate, occasionally ternate, ovate or ovate-lanceolate, 1·5–3 in. long, sometimes larger in fertile localities, glabrous and shining above, glaucous beneath. Bark reddish brown or dark brown, red inside, smooth in young trees, rough with deep vertical cracks in old trees. Wood hard, very close-grained, oily ; sapwood white, scentless, heartwood yellowish brown, strongly scented, used for carving and other fancy work, and largely distilled for its fragrant oil, which is used in perfumery and medicine. For distillation purposes the heartwood of the stem, branches, and roots is used, every part of the tree which contains heartwood down to about 1 in. in diameter

being utilized. The wood is sold by weight, and pound for pound is by far the most valuable wood in India, if not in the world.

Ordinarily the tree attains a height of 40 to 50 ft. and a girth of 3 or 4 ft., though larger specimens are sometimes met with. The largest tree recorded is one felled about 1874 in the Hassan district of Mysore, which had a girth of 8 ft., and yielded $1\frac{1}{2}$ tons of good heartwood ; it grew in sandy soil on the bank of a perennial river.

DISTRIBUTION AND HABITAT. The sandalwood tree is indigenous to the Indian Peninsula from Nasik and the Northern Circars southwards (Brandis). The principal sandal tracts, however, are confined to definite parts of Mysore and Coorg and to some districts of Madras. In northern Travancore, according to Bourdillon, it is apparently wild in the Anjinaad valley, and elsewhere is naturalized and well established both on the hills and in the low country in gardens and on waste land. In Bombay Talbot says it occurs throughout the Deccan trap region, where it rarely forms heartwood of marketable size ; the best and largest trees are in the Dharwar district and North Kanara along the Mysore border. He says that the total annual yield of marketable sandalwood from the Bombay forests does not exceed 100 tons, and adds that many attempts have been made at sandalwood planting in the Northern and Central forest circles, but these have invariably resulted in failure. Mr. Srinivasalu Naidu¹ says it is indigenous in the heads of ravines in the Gerumatergaon reserve round Borala in the Buldana district of Berar, but that most of the old trees have been cut away. Sowings in the Akola and Buldana districts have been successful, and so far the results attained hold out promise that considerable tracts of very poor forest in Berar will in time become valuable sandalwood areas by the artificial introduction of this tree. Sandalwood is grown in gardens and other places far outside its habitat, not only in the Peninsula but as far north as Saharanpur and Dehra Dun, and where conditions are favourable it sometimes tends to spread naturally where introduced. Attempts have been made in recent years to introduce the tree in certain forests in the dry zone of Upper Burma, but although the seed germinated well, the seedlings have not shown much promise, as they suffer much from drought in the hot season.

Mysore contains the most important sandal tracts in India, the present outturn being about 2,000 tons of heartwood per annum. The Mysore plateau contains a well-marked belt of sandal extending eastward to where the rainfall is about 35 in., and westward to where it is about 55 in. ; sandal is also scattered over the greater part of the state, but is not found in the driest parts in the north, where the rainfall is about 20 in. It is most plentiful in the Shimoga, Kadur, Hassan, Mysore, and Bangalore districts, and thrives best at an elevation of 2,000 to 3,000 ft.

In Coorg it occurs in the northern and north-eastern part of the province where the rainfall varies from 30 to 75 inches. The present outturn from natural forests is about 200 tons of heartwood per annum, but with tending operations and better estimates of yield the outturn will probably rise to 500 tons in the next fifteen or twenty years, and possibly to 1,000 tons or more in the distant future, as sowings are being vigorously prosecuted.

¹ Working Plan Report, Buldana, par. 58.

In the Madras Presidency sandal is found chiefly in the districts of Coimbatore Salem, the Nilgiris, and North Arcot ; it also occurs, sparsely or of small size, in Cuddapah, Bellary, Tinnevely, Trichinopoly, Kurnool, and South Canara, and is said to have established itself long in Chittoor and more recently in Anantapur, where it is tending to spread naturally. The most important sandal tracts in Madras are situated in (1) the Javadi and Yelagiri hill ranges in the Salem and North Arcot districts at elevations chiefly between 2,000 and 4,000 ft., but occasionally down to 1,200 ft., with a rainfall of 30–40 in. ; (2) the Shevaroy hills in the Salem district, at 1,500–4,500 ft., with a rainfall of 30–60 in. ; (3) the plateau lands of the Coimbatore district, at 2,000–4,500 ft., with a rainfall of 40–50 in. ; and (4) the south-eastern Wynaad of the Nilgiris district.

Speaking generally, it may be said that the tree flourishes best between 2,000 and 3,500 ft., though it ascends to over 4,000 ft. and descends in places as low as 1,200 ft. It flourishes, when planted, even at sea-level, but naturally it is a tree of the upland plateaux, growing chiefly on undulating ground, but often on hill-sides and in open spaces along the banks of rivers and in ravines.

The important sandal tracts lie in regions where the rainfall varies from 25 to 65 in., but the tree is occasionally found where the rainfall is above or below these limits, while it is sometimes cultivated in gardens where it is as high as 100 in. or more. Generally speaking, the climate within its habitat is comparatively cool, with a moderate rainfall, much sunshine, and long periods of dry weather. Frost is unknown, and the temperature varies as a rule from 50° to 95° F. The most common form of soil on which it occurs is a red ferruginous loam varying in fertility, the underlying rock often being metamorphic, chiefly gneiss. It is frequently found on rocky ground or on stony or gravelly soil, and is not exacting as to depth of soil. It shows the best growth on rich fairly moist fertile soil, for example in garden loam and on well-drained deep alluvium along river-banks. Trees grown on poorer ground, and particularly on stony or gravelly soil, although they do not attain such large dimensions, are said to have more highly scented wood, but this has not yet been definitely proved. The tree requires good drainage, and does not stand water-logged ground. It avoids saline and calcareous soils, and is not as a rule found on black cotton soil.

The sandal tree is not found in dense high forests of good growth, but occurs mainly in open scrub forests, hedgerows, among lantana bushes or bamboo clumps, and round the edges of cultivated lands. No doubt sandal has been preserved to some extent owing to the fact that on all lands, whether state or private, it has for long been regarded as a royal or reserved tree in Mysore and Coorg, and more recently so in Madras. Still, the earlier forest reservations were carried out mainly in types of forest containing teak and other timber trees where sandal did not occur, and in forests not burdened with rights of user. In this way sandal tracts largely escaped reservation, and the area of sandal in Government forests, which must be relied on for future permanent supplies, is not so great as it might have been, and the natural sandal-bearing area has become much restricted.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The tree is a true ever-

green. Mr. F. B. Dickinson¹ says the foliage gets thinner in protracted monsoons with continual rainy weather, and also in the dry season; a flush of new leaves appears during the early showers in May, and after the monsoon in October. The flowering and fruiting seasons appear to vary. Mr. Dickinson, writing from Coorg, says the flowering season lasts from February till April, and the fruits ripen in May and June and during the monsoon if a light one, or the ripening is sometimes put off till after the monsoon. Mr. D. E. Hutchins,² writing from Mysore, says the tree flowers at the end of the hot weather or early in the rains, and the fruit is ripe in a few months, usually by the close of the rains. Mr. P. M. Lushington³ says that in North Coimbatore there are two distinct periods of flowering and fruiting, one general and the other confined to only a portion of the trees, and these as a rule are of the dark-leaved kind. The ordinary flowering begins in May, and is at its full height by the end of June; the seeds begin to form in October, but the bulk do not ripen till November or December. The other flowering takes place from February 15, and is at its height in March, though it sometimes extends up to June; the fruit ripens in July and August, but there is some doubt as to the value of the seed produced. Mr. Rama Rao⁴ says its ordinary and general fruiting season extends from June to September, but it also bears fruit rather sparsely between November and February. He mentions that it is not uncommon to find at one and the same time trees laden with flowers and fruits in various stages from the nascent flower-bud to the ripe fruit ready to drop.

The flowers are purplish brown, unscented, in axillary or terminal cymose panicles. The fruit is a purplish black globose succulent drupe 0.3–0.5 in. in diameter, with a brown endocarp which is moderately hard but brittle and easily broken. The fruit-stones (Fig. 302, *a*) are globose, 0.2–0.3 in. in diameter; about 120 to 170 weigh 1 oz. The seed has a copious white albumen and a straight embryo. It retains its vitality for some time if kept dry, but is apt to rot with damp. The seeds are very subject to the attacks of rats and squirrels, which destroy them in quantities. Birds readily eat the fruits, and are important agents in disseminating the seeds, which they do not destroy.

Flowering and fruiting often commence at an early age; trees three or four years old have been noticed to flower, but it is not certain if they produce fertile seed. Mr. Lushington⁵ expresses the opinion that good seed can be obtained from all trees over twenty years of age. Good seed-years occur every year, with only occasional exceptions.

GERMINATION (Fig. 302, *b–d*). Epigeous. The fruit-stone cracks and the radicle emerges and at once descends. The hypocotyl elongates by very pronounced arching, the loop appearing above ground while the cotyledons, enclosed in the albumen, remain underground. The lower portion of the hypocotyl becomes very swollen and fleshy, the nutriment from the albumen being transferred to that portion of the seedling. After this transference of nutriment is completed the hypocotyl becomes erect. The seed is either carried above ground, soon falling off, or is left in the ground, where it rots. The cotyledons break off, remaining within the seed and leaving their petioles

¹ Ind. Forester, ix (1883), p. 64.

² *Ibid.*, x (1884), p. 208.

³ *Ibid.*, xxvi (1900), appendix, p. 14.

⁴ *Ibid.*, xxx (1904), p. 357.

⁵ *loc. cit.*, p. 15.



FIG. 302. *Santalum album* SEEDLING $\times \frac{7}{8}$

-Fruit-stone b - d—Germination stages e - g—Development of seedling during first season (g shows white cushion-like haustoria on roots of seedling, and attachment to roots of host)

attached to the stem in the form of a pair of stumps, above which the young foliage leaves quickly develop.

THE SEEDLING (Fig. 302).

Roots : primary root moderately long, flexuose, whitish, delicate ; lateral roots moderate in number, short or moderately long, fibrous, delicate, distributed down main root ; roots at an early stage develop nodular growths, the first signs of haustoria. *Hypocotyl* distinct from root, 1.4–3.5 in. long, fusiform, much swollen in lower part in earlier stages. *Cotyledons* : petiole 0.2–0.3 in. long ; lamina 0.2–0.3 in. long, ovate lanceolate, fleshy, yellow, outer surface convex, inner flat, remaining within the albumen of the seed. *Stem* erect, green, glabrous ; internodes 0.3–0.8 in. long. *Leaves* simple opposite or sub-opposite decussate, exstipulate, earlier leaves smaller than later ones. Petiole 0.15 in. long or less. Lamina 0.4–1.8 in. by 0.15–0.5 in., oblong lanceolate or elliptical, earlier leaves often oblique, apex and base acute, entire, glabrous.

Under average conditions nursery-raised seedlings attain a height of 8–10 in. in the first season and 1–2 ft. by the end of the second season, though this growth is often exceeded. Under less favourable conditions a height of not more than 4 or 5 in. may be attained in the first year. Mr. F. B. Dickinson¹ states that he has seen seedlings grow 3 to 4 ft. in the first year, and as much in the second year, and has seen some plants not three years from seed which were 11 ft. high.

Mr. Tireman has furnished the following measurements showing the height of young plants of different ages in sowings in Coorg :

Santalum album : height growth of young plants, Coorg.

Locality.	Date of sowing.	Mean height at age of							
		1 year.	2 years.	3 years.	4 years.	5 years.	6 years.		
		ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	
Malarubi near Kargode	1913	..	2 6	4 9	7 3	..	..	..	
	1914	1 11	5 2	7 6	..	..	..	..	
	1915	2 3	5 3	..	..	..	..	..	
Kurubara-panchi near Murkal	1911	..	..	..	5 7	7 10	9 8		

The seedling is sensitive to drought, and is readily killed by sudden exposure to the sun. It requires lateral shade, but is intolerant of low overhead cover even in the first year, and tends to damp off in the rains unless its head is freed. It is also sensitive to water-logging, and in cold wet soil is apt to rot. Seedlings are much subject to the attacks of insects, and are sensitive to this form of injury ; in the germinating stages and soon after the cotyledons, the fleshy hypocotyl, the young leaves, and the taproot are all readily attacked, and the seedlings may be killed off in quantity. Hares, deer, cattle, and goats browse on young plants, hares and deer in particular seeking them out and causing much injury. Rats and squirrels also damage them in their earlier stages. Rats are perhaps the worst offenders of all : they pull up young seedlings and eat the fleshy hypocotyls, but after the stems have hardened, that is, when the plants have attained an age of five or six months, this form of damage ceases.

One of the most important characters of the seedling, and of the plant

¹ Ind. Forester, ix (1883), p. 65.

in general, is the root-parasitism exhibited by it ; this character is considered below.

Further investigation is necessary into the question of the dying back of seedlings under certain conditions. Mr. P. M. Lushington has noted cases indicating that this has taken place in the second year, and remarks : ' In some sowings at Pecheruvu, Kurnool, A. W. Lushington going the year before I did said the one-year-old was a success and the two-year-old a failure. I found his failure to be a great success, but with a very careful search could find nothing in the then two-year-old coupe. Since that time I have constantly observed the same thing. I am talking of plants under the cover of scrub.' Mr. Lushington suggests that there may possibly be some relation between this apparent dying back and the formation of root-attachments which is not yet understood.

ROOT-PARASITISM. The fact that the sandal tree is a root-parasite was established in 1871 by Mr. John Scott, Curator of the Royal Botanic Gardens, Calcutta.¹ For many years the importance of this fact does not appear to have been realized in the silvicultural treatment of the tree, and Scott's work seems to have been lost sight of, for although its possible parasitic nature was at times alluded to vaguely and sometimes with expressions of doubt, no serious effort appears to have been made to carry out any scientific investigation into this most important character till Dr. C. A. Barber was led to examine the roots of the sandal in connexion with his study of the spike disease in 1902. ' Beginning with seedlings,' he writes,² ' I was much surprised . . . to find an abundance of connexions between their roots and those of other plants. There is no doubt that the young sandalwood will, if allowed the chance, at once attach itself to foreign plants. . . . When, however, I came to look into the root-system of the larger trees, I was astounded at the immense number of functional haustoria whereby the roots were actually attached to those of other plants. The sandalwood trees, wherever I have examined them, greedily attach themselves to the surrounding vegetation.'

Dr. Barber published the results of further investigations on the subject in two subsequent papers ;³ in the first he dealt with the root-system of sandal seedlings grown under different conditions and the formation of haustoria on the roots, and in the second he described the microscopic structure of the haustoria and their mode of attachment to the roots of host plants. These papers were followed by a more detailed description of the haustorium in the *Memoirs of the Department of Agriculture in India*.⁴ Based on the experimental cultivation of sandal seedlings in pots, and on a study of the haustoria developed under various conditions, the chief results of Dr. Barber's earlier investigations may be summarized as follows :

1. Seedlings grown in pure sand, without hosts, form a well-developed and much-branched root-system with a fine network of delicate rootlets ; this root-system is produced largely from the stores of nutriment in the seed, which are located after germination in the swollen hypocotyl. Many of the

¹ Journ. Agric. and Hort. Soc., Calcutta, ii. 287.

² Ind. Forester, xxviii (1902), p. 340.

³ *Ibid.*, xxx (1904), p. 545 ; and xxxi (1905), p. 189.

⁴ C. A. Barber, Studies in Root-Parasitism, Mem. Dept. Agric., Bot. Ser., vol. i, No. 1, pt. i, January 1906, and pt. ii, July 1907.

finer rootlets are covered with short root hairs, although these are usually too minute to be seen with an ordinary hand-lens. Certain of the rootlets develop small haustoria, also covered with root hairs, as if the plant felt its need of some outside assistance. Seedlings grown in pure sand are light green in colour, and although perfectly formed, are not well nourished.

2. Seedlings grown in a mixture of sand and vegetable mould, without hosts, assume a darker colour and a more healthy appearance. There is comparatively little branching in the root-system; the roots are thicker, as in the case of humus-loving plants, and there are fewer root hairs. In the specimens grown the roots were unhealthy, the rootlets dying quickly, and there was a remarkable absence of haustoria. The healthier appearance of the seedlings as compared with those grown in pure sand would indicate that a certain amount of nutriment is derived from the richer soil, apart from what is derived from the swollen hypocotyl. The unhealthy root-system indicates that it is doubtful if the raising of sandal seedlings in vegetable mould by itself is a wise practice.

3. Seedlings grown in pots with well-established plants of other species growing in them had a root-system differing little from that of the mature plant in nature. They varied greatly in the number of root-attachments formed, and, what is of importance, the number of attachments seemed to depend on the species of plant with which they were grown; thus there were no attachments in a pot full of roots of *Livistona* palm, while seedlings only a few months old had formed numerous attachments when grown with *Pterospermum Heyneanum*, *Tecoma stans*, *Casuarina equisetifolia*, and certain other species.

4. The presence or even nearness of foreign roots is not necessary for the development of haustoria on sandal roots, and haustoria will even attach themselves firmly to small pebbles. When a rootlet commences to form haustoria it usually does so in many places, so that rows of these are met with on certain roots, while others have none.

5. Seedlings grown in pure sand without the aid of a host have survived for over a year.

6. The haustoria on the roots of sandal seedlings arise from the external layers of the rootlet, unlike the lateral rootlets, which are formed deep in its tissues. If no host is met with it is probable that the haustorium remains small and ultimately withers away, but if a foreign rootlet is met with it grows rapidly, attaching itself closely to the rootlet and developing into a mass of white tissue, at first club-shaped, but later on adapting itself to and enfolding the surface of the root attacked, becoming elongated through the growth in length of the latter and assuming more or less the shape of a flattened bell. The usual dimensions of a fully developed haustorium are: height, 3-10 mm.; longer diameter, 2-12 mm.; shorter diameter, 2-8 mm. The formation of haustoria is more or less confined to the younger roots; the main roots, although clothed with large haustoria, probably take little part in the absorption of nutriment. The white cushion-like haustoria are exhibited in Fig. 302, *g*.

Since Dr. Barber drew attention to the importance of this question, others have recorded the results of their observations, chiefly as regards the extent

of root-parasitism exhibited and the species found to be most suitable as host-plants. In a series of experiments commenced in 1905-6, Rao Sahib M. Rama Rao found that sandal seedlings were incapable of growing beyond a year at the most unless nourished by attachment to the roots of other plants, without which they turned pale, withered, and died within a year of germination.¹ He also confirmed Dr. Barber's conclusions as to the selective habit of sandal in relation to its hosts, and found that although the sandal plant may attack the roots of almost any other plant, it shows a decided preference for and grows best in the company of certain species; of species selected for experiment, *Pongamia glabra* and cotton (*Gossypium arboreum*) proved the most favourable, *Albizia Lebbek* coming next, *Cleistanthus collinus* next, and teak (*Tectona grandis*) next.

Various observations regarding the species which act as hosts to the sandal tree have been recorded from time to time within recent years. Barber² in 1907 gave a list of 122 sandal hosts. Rama Rao³ has dealt in some detail with the subject in his paper on *The Host Plants of the Sandal Tree*. He points out that the sandal has been found to attack the roots of almost all species with which it comes in contact, though in very varying degree; it has also been found to form root-attachments with other sandal plants. As regards the suitability of various hosts, however, matters appear to be complicated by the fact that a species readily attacked in one locality may be sparingly attacked in another, and there are apparently other factors, such as the physical condition of the soil, which influence the degree to which the sandal attacks a given species. An exact classification of host plants according to their influence on the growth of the sandal would on this account alone seem to be difficult if not impossible, though the sandal does appear to show a decided preference for certain species. Rama Rao gives a list of 144 host plants observed and examined by himself and others, as well as 252 associates of the sandal in its natural habitat and elsewhere. Among good hosts included among the former may be mentioned *Acacia concinna*, *A. Intsia*, *A. Suma*, *Alangium Lamarckii*, *Albizia Lebbek*, *A. odoratissima*, *Bambusa arundinacea*, *Casuarina tomentosa*, *Cassia auriculata*, *Casuarina equisetifolia*, *Dalbergia Sissoo* (exotic), *Eucalyptus Globulus* (exotic), *Gossypium arboreum* (cotton), *Limonia acidissima*, *Mallotus philippinensis*, *Melia Azadirachta*, *Mimusops Elengi*, *Morinda citrifolia*, *Pongamia glabra*, *Thespesia populnea* (exotic), *Vitex Negundo*, *Wrightia tinctoria*, and *Zizyphus Oenophia*. This list is far from exhaustive. In addition the lantana is freely attacked, but this troublesome weed can hardly be recommended for introduction as a host, especially while the question of its possible connexion with the spike disease of sandal remains unsettled.

The choice of nurses for sandal must necessarily be restricted to plants suitable for other reasons than the mere fact of their being good hosts; thus short-lived plants, such as many shrubs, would be unsuitable by themselves, as their disappearance would mean the death of the sandal, while hosts with heavy shady crowns would suppress it. From an economic point of view, again, a valuable species would form a more suitable host than one of little or no value, other conditions being equal.

¹ Ind. For. Records, vol. ii, pt. iii.

² loc. cit., pt. ii, app. I.

³ Ind. For. Records, vol. ii, pt. iv, 1911.

Mr. C. C. Wilson¹ has given a list of 36 plants on which he has found sandal to be parasitic in South Vellore and North and South Salem. This list includes the two bamboos *Bambusa arundinacea* and *Dendrocalamus strictus*. Other writers had previously remarked on the favourable effect of bamboos on the growth of sandal. The chief objection to them, however, is the fact that they may flower and die at any time, and this in itself is sufficient to preclude their use as hosts; but apart from this, experience in Coorg has shown that bamboos require constant cutting to prevent the suppression of the sandal, and when they die they are a source of danger from fire.

SILVICULTURAL CHARACTERS. In its early stages the tree is partial to shade, and thrives under cover of hedgerows and thickets of scrub; in open country it has considerable power of pushing through scrub growth, and shows a tendency to free its head from the surrounding growth. Where there is an upper story of high forest, however, it rarely succeeds in pushing its way through the undergrowth. In its middle and later life it is intolerant of heavy overhead shade, but is often found growing under comparatively light cover. Although it forms a taproot most of its roots are surface feeders, and it produces long lateral roots not far below the surface of the ground; these may reach a length of 100 ft. or more. Root-suckers are freely produced where the roots are exposed or cut through, or where the parent tree has been felled and the stump grubbed up. Young trees coppice fairly well; older trees are said to have little or no coppicing power except on moist ground along the banks of watercourses; but since trees large enough to produce heartwood are always grubbed up, observations as to their coppicing power are not very extensive.

Frost is unknown in the natural habitat of the sandal. It is sometimes killed by long-continued drought. It often suffers from bark scorching caused by insolation and possibly to some extent by wind. This form of damage takes place mainly on the south-west side, and is most prevalent on young trees which have grown up with surrounding cover and have been suddenly isolated. It commences with a cracking and peeling of the bark in thin strips, and later develops into a long, more or less triangular blister, often extending 3 or 4 ft. up the stem, while in bad cases the wood is exposed to a considerable extent, and death may result. The best protective measure is to retain side cover round the bole as long as possible.

The leaves are readily browsed by cattle, goats, and deer, particularly in the dry season when grass is scarce, and much damage is done, more especially by goats and deer, unless the plants are well surrounded by bushes and thorny growth; the damage is often accentuated by the fact that graziers lop the tree to provide goat fodder. Cattle often nibble and rub the bark. The tree is extremely sensitive to fire, and may be killed outright or badly injured and rendered unsound: when the stems are killed new shoots are frequently sent up from the base. Mr. C. C. Wilson has advanced the theory that its susceptibility to damage by fire may be due in part to the fact that the roots bearing the haustoria themselves are killed by the heat and rendered incapable of performing their functions. The same theory may explain the fact sometimes observed that extremes of soil temperature are injurious to the sandal.

¹ Ind. Forester, xli (1915), p. 247.

SPIKE DISEASE. 'Spike' is the name given to a diseased condition of the leaves and twigs of sandal. This disease, the origin and nature of which is as yet obscure, has for years past been the cause of immense mortality among sandal trees throughout a considerable extent of the natural sandal-bearing areas. The annual loss caused by spike disease for some years past in Mysore and Coorg has been estimated at 5 or 6 lakhs and 1 lakh of rupees respectively (1 lakh of rupees = £10,000 nominal). As far as is known the disease is of comparatively recent origin. The first account of it appears in a memorandum written in 1899 by Mr. C. D. McCarthy, then Deputy Conservator of Forests in Coorg, although it seems to have been generally noticed prior to this. Mr. McCarthy thus describes the appearance of the disease :

'The new shoots and leaves of a tree, instead of presenting the graceful appearance natural to the species, begin to grow out stiff and straight ; the leaves also stand up stiff and erect like bristles, and as their arrangement is opposite and alternate, the shoot looks like a spike with four lines of erect leaves growing down it, something like a chimney brush. There is no discernible change in the new axis except that it grows out stiff and straight. As regards the leaves, in the first place the distance between the alternate pairs is greatly decreased, then the petiole and blade are from base to tip in one straight line, and lastly the blade is shorter, narrower, and more pointed. However, there is no sign of spot or sickness in the leaf substance. As the disease progresses the new leaves become still smaller, narrower, more pointed, and fewer each successive year, until the new shoots present the appearance of fine spikes bearing four rows of small bristles. After this the tree rapidly dies off. I have never seen recovery.'

Cases of recovery have, however, since been reported. Mr. McCarthy also notes the following additional characteristics : (1) spiked twigs appear at the commencement of the growing season, and affect the new shoots only ; there is no change in the leaves or branches which existed prior to the appearance of the abnormal growth ; (2) the abnormal branches never flower and fruit, although the rest of the tree may be normal in this respect and may bear flowers and fruits ; (3) root-suckers from a spiked tree are invariably spiked also (Dr. Barber, however, subsequently found an apparently healthy tree every root-sucker from which was spiked) ; (4) the growth of spiked twigs is far more active than that of normal twigs, the growing point remaining active long after the normal shoots have completed their annual growth, and there being little or no mark of separation between the successive annual flushes, so that it is difficult to determine the length of time a tree has been attacked.

The appearance of a spiked twig side by side with a normal twig is shown in Fig. 301.

Some years ago the spike disease was the subject of brief investigations by Drs. Barber and Butler ; the former issued his report on July 24, 1902,¹ and the latter on February 27, 1903.² Among other characteristics Dr. Barber noted the occurrence of phyllody, a peculiarity usually due either to excess of nutrition or to the stimulation of a parasite, though in this case neither of these causes was revealed. From a microscopic examination he also brought to light the significant fact that the tissues of the diseased branches were loaded with an excess of starch, and Dr. Butler found a similar excess of starch in

¹ Ind. Forester, xxix (1903), p. 21.

² *Ibid.*, App. series.

the internal tissues of affected leaves. This accumulation of starch, as Dr. Butler points out, is due to forced carbon-assimilation, by reason of which the tree or some isolated branches of it suddenly proceed to manufacture starch out of all proportion to the demand for it, with the result that growth is forced, the tree gets no rest, and dies of exhaustion, the result of starch poisoning. The cause of this intensified carbon-assimilation, however, remained untraced.

Neither Dr. Barber nor Dr. Butler were able to find any trace of a parasitic disease, both attributing the disease to physiological changes. An examination of the root-system made by Dr. Barber revealed the fact that in diseased trees the root extremities were invariably dead and rotten, while their haustoria were absent or dead. He concluded, therefore, that there were strong grounds for assuming that the disease is communicable through the roots, an assumption strengthened by the fact that when it appears in a locality it tends to spread progressively from tree to tree. For the same reason Dr. Butler concluded that spike is a definite and communicable disease, of which the virus spreads from root to root, and that injury by fire might be a predisposing cause to this as to other diseases. He made a large number of inoculations with different parts of the diseased tissues, but these all failed to communicate the disease to healthy parts.

Various observations on the occurrence of the disease and theories as to its origin have been recorded from time to time, and the Mysore Government some years ago offered a handsome reward to the discoverer of its true origin and of an effective and practicable remedy for it, but the reward has never been earned. There is one point on which observers appear to be generally agreed, namely, that the disease is particularly prevalent in lantana-infested localities, though the connexion of the two has not been definitely determined. The disease is not, however, by any means confined to lantana-infested tracts, and has been noticed in localities where there is no lantana present. Rao Sahib M. Rama Rao¹ has advanced a theory to account for the connexion between lantana and spike disease. He suggests that in a lantana-infested area where the sandal has to rely mainly or entirely on the lantana as a host plant, the root-system of the latter becomes weakened by the demands of the sandal, and the latter in turn suffers, its root-ends and haustoria dying off. The process of assimilation by its leaves, however, continues, starch being formed which cannot be converted into tissue-forming material since the supply of water and salts from the roots is cut off, and the plant eventually dies, since fresh adventitious roots are rarely if ever formed from the older parts of the root-system. In this case fire would accentuate the exhaustion and decay of the lantana and sandal roots.

Experiments carried out since 1911 in demarcated plots in badly affected areas in Coorg have shown that the uprooting of lantana is followed by a very considerable decrease in the percentage of trees attacked. In the same province an experiment has been in progress to test the effect of digging trenches round healthy trees in the vicinity of diseased trees. This appears to have been effective to a considerable extent, and seems to strengthen the assumption that the disease is communicated through the roots.

Although he recognized that the question of treatment of the disease is

¹ Ind. Forester, xxx (1904), p. 56.

difficult in the absence of any precise knowledge of its nature, Dr. Butler in 1903 suggested two measures based on the assumption that the disease is an infectious or contagious one, communicable through the roots, namely, (1) to make a complete clearing of trees in a strip at least 100 yds. wide round all affected areas, and (2) to uproot all spiked trees as soon as the disease appears, utilizing any saleable material and burning all the refuse.

The policy of uprooting all affected trees has been pursued steadily in Coorg, and up to 1915 about 340,000 trees, chiefly immature, had been uprooted in that province; the disease, however, continued to make headway, and in 1916 it was found to have spread across what had hitherto been regarded as its northern limit.

An important contribution to the literature on spike disease was furnished by Dr. L. C. Coleman in 1917, with the publication of the results of detailed investigations carried out in Mysore.¹ Dr. Coleman's experiments showed that the disease can be communicated by grafting diseased scions on to originally healthy stock. They also showed that some time elapses before the disease appears outwardly, although there is always internal evidence of it in the shape of starch formation before its outward appearance; the disease starts nearest the point of grafting and spreads outwards, extending to the roots and causing the death of the root extremities and haustoria. Dr. Coleman thus concluded that spike is not primarily a root disease, since it can be communicated to the roots from infection above ground; it has not yet been determined if it can be communicated from root to root. Dr. Coleman further concluded that as there is no evidence of fungus or insect attack the disease, which is an infectious one, is in all probability produced by a virus whose active principle is an ultra-microscopic organism. Experiments in injecting filtered extracts made by macerating in distilled water fresh spiked leaves and twigs, in order to ascertain if the organism or virus could be transmitted in this way, gave negative results, all the trees inoculated remaining healthy. It may be noted that other species besides sandal are attacked by spike disease, notably *Zizyphus Oenophia*, and Dr. Coleman has demonstrated the communicability of the disease, by grafting, in the case of this plant as well as of *Stachytarpheta indica*. Dr. Butler had previously recognized the analogy of spike to certain obscure plant diseases, notably the disease known in America as peach yellows, and this view Dr. Coleman corroborates. Other diseases bearing some resemblance to spike are peach rosette, the mosaic disease of tobacco, and the leaf roll disease of potatoes.

The question of the method of communication of the disease is still obscure. In the case of trees in root contact, Dr. Coleman considers that it is most probably communicated through the roots, but this does not explain how spike suddenly appears in isolated situations. He suggests the possibility of spread through diseased seeds carried by birds or otherwise, through the agency of insects, particularly sucking insects, as carriers of the virus, or by infection from other plants attacked by a similar disease. This question is being further investigated.

A theory recently propounded by Mr. R. S. Hole, as a result of field investigations in Coorg and garden experiments at Dehra Dun, attributes

¹ Spike Disease of Sandal, Dept. of Agric., Mysore State, Mycol. Ser., Bull. No. 3, 1917.

spike to quite a different cause from that to which Dr. Coleman attributes it. The theory advanced by him in a note published in October 1917¹ is to the effect that the diseased condition known as spike is not due to a specific parasitic organism or virus, but that it is merely a pathological condition due to an unbalanced circulation of sap which may be caused by a number of different factors, which are able to reduce the quantity of water supplied to the leaf surface. Unbalanced sap circulation is caused by the gradual reduction of the water-supply below that which is required for a balanced circulation, and this results in an accumulation of carbohydrates such as starch in the leaves and twigs, which gradually cuts off the food supply necessary for the health of the roots. Four factors in particular have been observed to be the apparent primary causes of unbalanced sap circulation resulting in spike, namely fire, death or damage to hosts, partial suppression by lantana or other growth, and the exposure of trees hitherto growing under shade. Additional factors which, it is considered, will probably be found to be responsible in at least some cases are drought, bad soil-aeration, and damage by insects.

As regards Dr. Coleman's grafting experiments, Mr. Hole contends that the results may be explained otherwise than by assuming the existence of a virus or organism, namely, by the transference of starch—after conversion to soluble sugars by the enzymatic activity of the stock—from the scion to the stock, and its subsequent deposition in the tissues of the latter in the form of an excess of starch owing to weakened enzymatic activity caused by this transference.

It is admitted that this theory requires proof, and steps are being taken to carry out a series of careful experiments to test it. In anticipation of proof, the chief measures necessary to prevent spike are indicated, on the basis of the theory, to be (1) fire-protection, (2) elimination of lantana by uprooting, (3) maintenance of good host plants and avoidance of severe damage to them, (4) provision of free and natural expansion of the crown of sandal plants from early youth, (5) careful and gradual freeing of trees which are more or less suppressed, (6) provision of light side shade to avoid damage from drought and sun-scorch, with free overhead light except in dry localities, (7) prevention of heavy growth of grass and herbaceous plants, which are bad hosts, (8) prevention of compacting of the surface of heavy soil by grazing.

Much experimental work remains to be done on the basis of the theories advanced by Dr. Coleman and Mr. Hole respectively, before any definite conclusions can be reached as to the primary cause of spike disease and the measures necessary for preventing or eradicating it. But the importance of investigating the disease from every possible standpoint is fully realized, and every facility is being given to those concerned in the investigations. Definite results, however, are still awaited.

NATURAL REPRODUCTION. Natural sandal seedlings are to be found mainly under bushes, hedgerows, and scrub, and not as a rule in the open. This is due not only to the fact that birds settle in such growth and drop the seeds, but also to the fact that the seedlings require protection, on the one hand from excessive drought and the heat of the sun, and on the other from

¹ Ind. Forester, xliii (1917), p. 429.

browsing animals ; this protection they receive under cover of bushes and hedgerows, particularly of thorny species. Seedlings perish in large numbers if exposed to excessive drought or to a hot sun, while on the other hand soil moisture, if not excessive, is an important factor, as may be seen from the manner in which sandal often reproduces itself along the banks of streams. In dry localities seedlings which have not perished altogether have been observed to die back to ground-level for a year or two and eventually to establish themselves. Damping off of seedlings owing to an excessive amount of dense wet herbaceous undergrowth is in some situations a hindrance to reproduction.

Natural seedlings suffer much in their earlier stages from the attacks of rats, while hares also seek them out readily ; as the plants grow larger, deer, goats, and cattle browse them eagerly if they are not protected by bushes.

Lantana acts as a good nurse to sandal in its early stages, and if the growth is not too dense the sandal is often able to make its way through it : a dense growth of lantana, however, is sufficient to kill out any seedlings that may appear. The great risk of fire in lantana-infested areas is in itself so great a danger to sandal reproduction as to outweigh all advantages it may possess as a nurse.

Outside its natural habitat the tree often shows a marked tendency to spread naturally by the agency of birds. Thus in North Chanda, where it has been planted, the seed has spread from the plantations and natural reproduction is springing up on the shady banks of neighbouring streams. In the Poona district natural reproduction of sandal is in some places tending to replace *Acacia arabica* on riverside areas. In the red sanders plantation at Kodur in the Cuddapah district, Madras, formed in 1865, other trees, including sandalwood, were subsequently introduced ; from the seed of these trees sandal has since spread naturally over the whole area of the plantation. In the Narsingarh State, Central India, sandal originally planted in gardens has reproduced itself freely in the neighbourhood of wells and streams, where the soil is moist and there are shady thickets of trees and undergrowth. Near Ajmer in 1884 Mr. A. E. Lowrie¹ noted the presence of good natural reproduction of sandal under bushes on poor shallow soil, the seed having been spread by birds from a few trees planted in a garden several years previously.

ARTIFICIAL REPRODUCTION. Numerous plantations of sandal, dating from 1870 or perhaps earlier, have been formed in Mysore, Coorg, North Coimbatore, and the Nilgiris, some by transplanting from the nursery and others by dibbling or sowing *in situ*. The history of these is difficult to trace, but in the majority of cases failure is recorded. Often the plantations appear to have succeeded for the first ten years or longer, after which the plants became unhealthy and died off by degrees. A few plantations have proved moderately successful. Various reasons have been given for the numerous failures. In many cases failure must have been due to the fact that the parasitic nature of the sandal was insufficiently realized, for there are various records of transplanting as well as of direct sowing being carried out in open glades or clearings where no host

¹ Ind. Forester, x (1884), p. 261.

plants were available, and such operations invariably resulted in failure. Again, during cleaning operations the complete removal of the surrounding scrub growth has resulted in the death of the sandal; at the time death was attributed to the sudden exposure of the plants, but it was no doubt due also, if not altogether, to the removal of the host plants. Other plantations appear to have failed for want of attention, having suffered much from browsing by deer and other animals, from suppression by climbers, lantana, and other vegetation, and in some cases even from fire and from lopping.

Transplanting from the nursery was the chief method of creating plantations in the early days. This was quite successful provided care was taken, but as a rule it proved very costly. It was usually found necessary to transplant in baskets or bamboo or tile cylinders owing to the sensitiveness of the seedling to damage to the root-system. More recent experiments have shown that it is advisable to raise host plants along with the sandal, seeds of both being sown in the cylinders, rather than to raise the sandal seedlings alone and to trust to their finding their own hosts after being transplanted. The seed should be sown in the cylinders about February–March, and the plants put out in the rainy season when about 3–6 in. high; large plants are transplanted at greater risk, owing to the danger of disturbing their root-attachments. Germination usually takes place about 1–3 months after sowing; some seed sown in a pot in September at Dehra Dun did not germinate until the following June.

It is now many years since transplanting on a large scale has been abandoned in favour of dibbling *in situ*; the latter has in many instances proved very successful, and is much cheaper than transplanting. Care is always necessary to dibble underneath bushes. One of the chief dangers is the damage done by rats, and in Coorg Mr. H. Tireman has found it advisable to disturb the ground as little as possible during dibbling, in order not to attract these animals. The seed is pressed into the ground with the thumb as soon as the soil has been softened by the early showers preceding the monsoon, the earlier the better. By dibbling underneath bushes in this way he has succeeded in stocking considerable areas successfully, the cost, after preliminary experience had been bought, amounting to about Rs. 15 per acre; it is proposed to continue similar operations in future at the rate of 150 to 200 acres a year.

The question of selecting suitable nurses in connexion with the artificial reproduction of sandal has already been alluded to, and it has been mentioned that care is necessary to select species which are likely to survive until the sandal attains maturity. *Casuarina* has proved an excellent nurse in the earlier stages, but, as Mr. Pigot notes,¹ it survives on the Mysore plateau for only about fifteen to twenty-five years, and the chances are that the sandal would die out with it.

Wherever deer or cattle are to be feared, the fencing of sandal plantations is necessary. Fire-protection is essential. The tending of plantations is dealt with in the next section.

SILVICULTURAL TREATMENT. The method of working the sandal tracts hitherto has been of a somewhat rough and ready nature, consisting of selection

¹ Ind. Forester, xxv (1899), p. 404.

or improvement fellings varying in detail. In some localities the spike disease has to a large extent controlled fellings by necessitating the removal of dead or affected trees as rapidly as possible. Some working plans have prescribed a minimum girth limit for sound trees; in Coimbatore the limit has been fixed at 32 in. girth, and in Salem at 36 in. girth at breast-height. A recent working plan for the Javadi and Yelagiri hills¹ prescribes the removal of dead and dying trees only, sound trees which are capable of continuing to grow satisfactorily being retained. In this plan a short felling cycle, namely six years, has been adopted. In other plans the felling cycle varies from seven to thirteen years.

Reproduction is secured partly by natural means, the result of protection and tending to the extent possible, and partly by artificial means, dibbling under bushes being the method now in vogue. Protection from fire, and as far as possible from grazing and other forms of injury, is supplemented by tending operations whereby sandal plants, whether of natural or of artificial origin, are saved from suppression. In these tending operations care is necessary not to remove completely any scrub or trees which act as host plants, but merely to free the heads of the sandal plants where they are in danger of suppression. Climbers are also systematically cut.

In the absence of accurate knowledge regarding the nature of the spike disease and the means necessary to counteract it, it is difficult to devise any special system of management for the sandal other than the somewhat rough method of selection hitherto in force, and in the meantime, provided measures are taken to ensure adequate reproduction, it is doubtful if this method of working could be much improved on.

Trees which are felled are uprooted, all but the smaller roots being dug up; the larger roots yield an appreciable amount of scented wood. Stringent rules are framed to prevent the theft of this valuable wood during felling and subsequent transport of the material to the sale dépôts.

RATE OF GROWTH. The visibility of the concentric rings varies greatly. On some specimens they are quite indistinguishable, while on others they are distinguishable in varying degree. In 1917 and 1918 I had an opportunity of examining nine sections from Coorg and 39 sections from Mysore, cut at a height of 6 in. from ground-level from trees in plantations of known age. It was found that in some cases the rings were fairly distinct on a dry smooth surface: water usually made them more distinct, and black coffee had a similar effect, but aniline dye obscured them. The following were the general conclusions reached after examining the 48 sections in question:

1. The concentric rings, where distinguishable, were almost certainly annual, since they corresponded more or less to the known rate of growth on that part of the radius on which they were clearly visible.

2. The specimens were obtained from different localities and types of soil and from trees of various ages and rates of growth; these factors did not appear to have any decided effect on the clearness of the rings, though in very slow-grown specimens the rings were so close together as to be more difficult to distinguish than in the case of fast-grown specimens. On the sapwood the rings were usually, but not always, more distinct than on the heartwood.

¹ Working Plan for the Javadi and Yelagiri Hills, C. C. Wilson, 1916.

3. In only one case did the number of rings counted coincide with the correct age of the section ; as a rule it fell far short of it, and frequently a recount gave a different result from the original counting, owing to the indistinctness of the rings. On some of the sections it was impossible to form even a rough estimate of the rate of growth, hardly any of the rings being visible. In the case of 33 of the Mysore sections, in which the rings were sufficiently clear but the number counted fell short of the correct age, this discrepancy amounted to twelve years for an average correct age of thirty-seven years, representing a discrepancy of 32 per cent.

4. So far as the specimens examined are concerned, and they are representative of varying conditions, the only conclusion to be drawn is that ring-countings cannot be relied on to give anything approaching an accurate estimate of the rate of growth except in occasional individual cases.

Statistics regarding the rate of growth of sandal are not as complete as they might be. The following measurements of planted trees of known age may be quoted :

1. Bylur plantation, North Coimbatore, measurements made in 1894 and recorded by Mr. P. M. Lushington,¹ but considered by him to be above the average.

Santalum album : rate of growth in plantations, Bylur, N. Coimbatore.

Age. years.	Mean height. ft.	Mean girth. in.	Age. years.	Mean height. ft.	Mean girth. in.
16	12	9	21	14	11
17	13	10	22	14	11
18	13.5	14	23	15	12
19	13	13	24	15.5	12
20	15	13	..	..	..

Other measurements recorded in the same plantation are—(a) age nineteen years, mean girth 9½ in., mean bole 9½ ft. ; (b) age twenty years, mean girth 12¾ in., mean bole 8½ ft.

2. Mr. F. B. Dickinson² recorded trees planted at Fraserpet, Coorg, eighteen years old, 25 ft. high, 18 in. in girth, with heartwood about 2 in. in diameter.

3. Mr. A. E. Lowrie³ recorded a tree near Ajmer on very poor rocky soil, occasionally watered, age eight years, height 12 ft., girth 9 in.

4. Mr. J. L. Pigot⁴ states that he has measured trees up to 18 ft. high in seven years, the result of dibbling along with casuarina ; another tree similarly raised attained a height of 35 ft. and a girth of 18 in. in twelve years.

In 1917 Mr. Tireman furnished me with the following results of measurements of plantation-grown and natural trees in Coorg, which were measured in 1913 and remeasured in 1917 :

¹ Notes on the Sandal Tree in Southern India, 1900.

² Ind. Forester, ix (1883), p. 65.

³ *Ibid.*, x (1884), p. 261.

⁴ *Ibid.*, xxv (1899), p. 398.

Santalum album : rate of growth, Coorg.

Serial No.	Locality.	Elevation. ft.	Rainfall (approximate). in.	Age at first measurement. years.	No. of trees measured.	Girth.		Mean annual girth increment for 4 years' period. in.	Remarks.
						1913 in.	1917 in.		
1	Kargode (plantation)	3,300	65	26	23	14.20 (mean)	15.64 (mean)	0.36	Plantations neglected for several years prior to first measurement, but tended subsequently.
2	Kattepura (plantation)	3,100	60 or less	16	37	9.05 (mean)	10.75 (mean)	0.42	
3	Mullur village (natural trees near Kargode plantation)	3,330	65	..	19	4 to 40	..	0.15	Not tended prior to 1913, when they were freed from suppressing shade.
4	Somwarpet (natural trees)	3,600	80	..	10	3 in. to 3 ft.	..	0.16	Trees growing on a grassy down, not cultivated.
					12	3 in. to 3 ft.	..	0.3	Trees growing in a neighbouring coffee garden, more or less cultivated.

The rate of growth deduced from measurements in 1918 in twenty plantations of known age in Mysore was as follows :

Santalum album : rate of growth in plantations, Mysore.

Age. years.	Mean girth.		Mean height. ft.	Age. years.	Mean girth.		Mean height. ft.
	ft.	in.			ft.	in.	
5	0	1.5	3.5	30	1	5	18
10	0	6	7	35	1	7	20.5
15	0	9.5	10	40	1	9	22.5
20	1	0	13	45	1	10.5	24.5
25	1	2.5	15.5	50	2	0	26.5

Perhaps the most exhaustive measurements based on ring-countings are those recorded by Mr. C. C. Wilson in the form of curves in the working plan for the Javadi and Yelagiri hills, 1916, of which the following is a summary :

Santalum album : rate of growth, Javadi and Yelagiri hills, based on ring-countings.

Age. years.	Mean height.		Mean diameter at 4 ft. in.	Mean volume per tree. cub. ft.	Age. years.	Mean height.		Mean diameter at 4 ft. in.	Mean volume per tree. cub. ft.
	ft.	in.				ft.	in.		
5	3.4	0.4	..	..	35	..	6.7	2.26	..
10	6.3	1.0	..	..	40	..	7.8	3.23	..
15	10.0	1.9	..	..	45	..	8.7	4.55	..
20	15.2	3.0	0.59	..	50	..	9.4	6.70	..
25	19.0	4.1	1.00	..	55	..	10.0	..	..
30	21.3	5.4	1.54	..	60	..	10.5	..	..

The following measurements recorded by Mr. P. M. Lushington, based on ring-countings on stumps of natural trees at Bylur, may be compared with the plantation measurements in the same locality given above :

Santalum album : rate of growth of naturally-grown trees, Bylur, N. Coimbatore.

Age. years.	Mean girth.		Age. years.	Mean girth.	
	in.	..		in.	..
9	4.75	..	26	16.25	..
17	7.25	..	32	21	..
20	12.5	..	..	..	..

At Bylur the growth was found to vary from 7 to $9\frac{1}{4}$ rings per inch of radius, and in the Bhavani *talug* from $6\frac{1}{2}$ to $7\frac{3}{4}$ rings. These figures have formed the basis of rough working plans in North Coimbatore, under which the minimum girth at which sound trees may be felled was fixed at 32 in., corresponding to an estimated age of at least forty years.

Records of measurements in different localities show averages varying from $6\frac{1}{2}$ to 10 rings per inch of radius for natural trees, giving mean annual girth increments varying from about 0.6 to 1 in. On the whole, therefore, the sandal may be regarded as a rather slow-growing tree, though its growth is fast compared with that of many of the scrub species associated with it.

The age of commercial maturity has been variously estimated at from forty to sixty or even sixty-five years, the lower age applying more particularly to plantations. These estimates, however, are very rough.

YIELD OF HEARTWOOD. As the heartwood alone is scented it is the only valuable portion of the tree. Mr. P. M. Lushington says it commences to form rapidly at about twenty years of age, and is at its prime between thirty and fifty years, when the trees vary from 2 to $3\frac{1}{2}$ ft. in girth. Mr. Hutchins estimated that the average formation of heartwood per annum in Mysore up to the age of commercial maturity was about 0.15 cubic feet. Mr. Lushington gives the following outturn of cleaned heartwood from trees cut in 1898 in Punnachi, North Coimbatore :

Santalum album : outturn of heartwood, Punnachi, N. Coimbatore.

Girth class. in.	Number of trees.	Average weight of scented wood per tree. lb.	Girth class. in.	Number of trees.	Average weight of scented wood per tree. lb.
9-12	31	14	24-30	29	63
12-15	64	20	30-36	12	107
15-18	79	21	36-42	1	62
18-21	61	34	42-48	2	269
21-24	45	43			

Mr. C. C. Wilson, in his working plan for the Javadi and Yelagiri hills, gives the following outturn figures based on a number of measurements :

Santalum album : outturn of heartwood, Javadi and Yelagiri hills.

Weight of heartwood per tree.			Weight of heartwood per tree.		
Girth of tree.	Quarters.	Equivalent in lb.	Girth of tree.	Quarters.	Equivalent in lb.
ft. in.			ft. in.		
2 0	4.4	123	4 0	25.9	725
2 6	7.8	218	4 6	30.7	860
3 0	11.5	322	5 0	34.3	960
3 6	18.7	524	5 6	38.0	1,064

Mr. Rama Rao¹ gives the following outturn figures collected in 1902-3 and 1903-4 from trees growing at different elevations on the Salem Javadis :

¹ Ind. Forester, xxx (1904), p. 251.

Santalum album : outturn of heartwood, Salem Javadis.

Girth class. in.	No. of trees.	Weight of heartwood per tree. lb.	Girth class. in.	No. of trees.	Weight of heartwood per tree. lb.
16-18	2	81	43-45	47	396
19-21	..	..	46-48	24	392
22-24	1	84	49-51	8	529
25-27	4	126	52-54	6	659
28-30	8	147	55-57	5	578
31-33	5	89	58-60	5	699
34-36	3	647	61-63	1	496
37-39	103	299	64-66	2	495.5
40-42	73	318			

The factors which govern the formation of heartwood and the yield of oil from heartwood produced under different conditions are as yet imperfectly understood. In 15 samples analysed by Puran Singh the oil value varied from 0.85 to 5 per cent. : ¹ he notes that the range given by Gildmeister and Hoffman is 3 to 5 per cent., and that given by Parry is 1.5 to 6 per cent. The yield obtained in Europe is usually about 3 to 6 per cent., while in India the average yield is said to be about 2.5 per cent. ; the Kanauj distillers in the United Provinces, however, are said to obtain about 5 to 6 per cent., and to regard wood yielding less than this as inferior. The analyses carried out by Puran Singh showed generally that wood of trees grown on dry rocky ground is harder and richer in oil than that grown in fertile soils, though further analyses are necessary to decide this question definitely.

It was at one time held that scented heartwood is not formed at low elevations, and particularly near sea-level. Mr. P. M. Lushington quotes numerous figures of outturn exhibiting great variation even in the case of trees grown under apparently similar conditions ; on the whole his statistics indicate that scented wood appears to form more quickly at the lower elevations, but to increase less in proportion to the growth of the tree than does that formed in trees grown at the higher elevations. The tests carried out by Puran Singh were not exhaustive enough to decide the question of elevation in its effect on the yield of oil.

That scented heartwood is produced at low elevations has been definitely established. Mr. F. B. Dickinson examined a tree at sea-level in a garden on the coast at Cannanore and found that it had heartwood as strongly scented as any grown at higher elevations. Mr. Rama Rao ² records the results of an examination of a tree believed to be about thirty years old at sea-level at Pondicherry with moderately well developed scent ; he mentions that near sea-level on deep soils, both rich and sandy, the development of scented heartwood appears to be much slower than in the natural habitat of the tree. He gives further instances of the formation of scented heartwood (1) at Quilon, at sea-level, (2) on the Thirumalai (Jasper hill) near Trivandrum, at 400 ft., (3) in the village of Navaikulam, near Attengal, at 200 ft.,³ (4) at Kurnool, at 900 ft., and (5) at Vizagapatam at sea-level ; in this case the scent was slight, owing probably to the fact that the tree was young and immature.⁴ In

¹ Memorandum on the Oil Value of some Sandal Woods from Madras. For. Bull., No. 6, 1911.

² Ind. Forester, xxxiv (1908), p. 151.

³ *Ibid.*, p. 715.

⁴ *Ibid.*, xxxii (1906), p. 393.

none of these cases, however, was the percentage of oil determined by analysis.

The effect of host plants on the production of heartwood and oil, if they do influence it in any way, has never been studied ; it is possible that such a study may reveal to some extent the cause of the variations in the production of heartwood and oil in the case of trees grown under similar conditions of locality.

ORDER LII. EUPHORBIACEAE

This order contains a large number of Indian woody species, but no timber trees of first-class importance. The best timber tree is perhaps *Bischoffia javanica*, while some are common accessory species, for instance *Mallotus philippinensis*, *Phyllanthus Emblica*, *Bridelia retusa*, and *Cleistanthus collinus*. The boxwood, *Burus Wallichiana*, is valuable, but comparatively scarce. Of species favouring moist and even swampy ground may be mentioned *Bischoffia javanica* and *Trewia nudiflora*, while *Putranjiva Roxburghii* is found most typically on moist river alluvium. Of specialized xerophilous trees and shrubs some species of *Euphorbia* which have fleshy stems and grow on dry rocky ground are the most typical. Many species have poisonous properties in their milky juice, seeds, or fruits. Of trees of economic value by far the most important is the Para rubber tree, *Hevea brasiliensis*, now extensively grown in the East, including India and Burma. A somewhat less important exotic rubber tree, which grows well in some parts of India and Burma, is the Ceara rubber, *Manihot Glaziovii*. These two rubber trees are of interest rather to the planter than to the forester, and are therefore very briefly dealt with here.

Genera 1. EUPHORBIA, Linn. ; 2. BISCHOFFIA, Bl. ; 3. BRIDELIA, Willd. ; 4. PUTRANJIVA, Wall. ; 5. PHYLLANTHUS, Linn. ; 6. CLEISTANTHUS, Hook. f. ; 7. BUXUS, Linn. ; 8. BACCAUREA, Lour. ; 9. MALLOTUS, Lour. ; 10. TREWIA, Linn. ; 11. EXCAECARIA, Linn. ; 12. SAPIUM, P. Br. ; 13. MACARANGA, Thouars ; 14. CROTON, Linn. ; 15. JATROPHA, Linn. ; 16. HEVEA, Aubl. ; 17. MANIHOT, Adans.

1. EUPHORBIA, Linn.

This genus, consisting chiefly of herbaceous plants, contains a few xerophilous shrubs or soft-wooded trees with fleshy branches and copious milky juice, characteristic mainly of dry localities, where they are sometimes useful for clothing dry rocky hill-sides and as nurses under which seedlings of other species obtain protection and are enabled to establish themselves. They grow from cuttings, pieces of the fleshy branches 1-2 ft. long striking readily : it has been found that cuttings grow best if planted in the hot season, not in the rains. Hedges can be easily formed in this way, while on dry hill-sides this form of propagation is also useful.

Species 1. *E. Nivulia*, Ham. ; 2. *E. nerifolia*, Linn. ; 3. *E. Royleana*, Boiss. ; 4. *E. antiquorum*, Linn.

1. *Euphorbia Nivulia*, Ham. Vern. *Thor*, Hind. ; *Sij*, Beng. ; *Shasaung*, Burm.

A bushy tree 15–30 ft. high, with branchlets terete, not angular, usually whorled, and spirally or vertically arranged prickles. Bark thick and corky when old. Common on barren rocky ground in many parts of India and in the drier parts of Burma.

2. *Euphorbia nerifolia*, Linn. Vern. *Neurang*, Mar. ; *Zizaung*, Burm.

A shrub or small tree up to 20 ft. high with sharp stipular thorns on tubercles arranged in vertical or spiral lines. Common on waste lands and near villages in India and Burma. Wild on poor rocky ground.

3. *Euphorbia Royleana*, Boiss. Vern. *Thor*, Hind.

A small tree attaining a height of 15 ft., with 5- to 7-angled branchlets. Common on the outer hot dry slopes of the western Himalaya, chiefly between 3,000 and 5,000 ft., where it is often gregarious (see Fig. 303). It is not browsed, and is often plentiful on grazed areas, the young plants springing up in abundance. It is frequently associated with *Pinus longifolia* where the latter is open enough to allow of its growth, for it is a strong light-demander.

4. *Euphorbia antiquorum*, Linn. Vern. *Tidhara-send*, Hind. ; *Narsej*, Mar. ; *Shasaung-pyathat*, Burm.

A small tree with jointed branches, 3- or sometimes 5-angled. Common in the drier forests throughout Burma, also in parts of the Indian Peninsula. Often cultivated for hedges.

2. BISCHOFFIA, Blume.

Bischoffia javanica, Bl. Vern. *Kaen*, *pankain*, *kot semla*, *irum*, *paniala*, *bhillar*, Hind. ; *Uriám*, Ass. ; *Gobra nerul*, *nilimara*, Kan. ; *Thondi*, *milachit-tyan*, Tam. ; *Pogaungsa*, *aukkyu*, *ye-padauk*, Burm.

A large deciduous or evergreen tree with a large shady crown and shining dark green trifoliate leaves. Bark dark grey, fairly smooth, inner cortex soft, juicy, and astringent. Wood red, durable, particularly under water, used for piles, bridge-construction, building, railway sleepers, and other purposes. Owing to the soft juicy astringent cortex the trees are sought after by tigers for the purpose of cleaning their claws, and in places where these animals abound the bark of the trees is often deeply scored with their claw-marks.

DISTRIBUTION AND HABITAT. Sub-Himalayan tract and outer valleys from the Ravi eastwards, rather scarce in the west, becoming common in the east, Assam, Chittagong, Burma, Chota Nagpur, and the Indian Peninsula. The tree is characteristic of moist shady ravines, river-banks, and swamps. In the western sub-Himalayan tract it is one of the species of the swamp forests, where it occurs with *Eugenia Jambolana*, *Trewia nudiflora*, *Ficus glomerata*, *Albizia procera*, *Diospyros Embryopteris*, *Putranjiva Roxburghii*, and other species. In the eastern sub-Himalayan tract it is common in low-lying moist savannahs, along streams, and in swampy ground, but is also found in some quantity on sandy alluvium on drier savannah tracts along with *Bombax malabaricum*, *Terminalia Chebula*, *Dillenia pentagyna*, *Premna*, *Callicarpa*, and other species. In southern India it occurs in evergreen forests with *Vitex altissima*, *Mesua ferrea*, *Litsaea zeylanica*, *Heritiera Papilio*, and many other species, as well as in other moist types of forest. In the Western Ghats it is fairly common in evergreen forests.



FIG. 303. *Euphorbia Royleana* on the hot dry slopes of the outer Himalaya at 4,000 ft.. Puniab.



FIG. 304. *Phyllanthus Emblica*, Dehra Dun

LEAF-SHEDDING, FLOWERING, AND FRUITING. In moist localities the tree is sometimes evergreen, but in drier situations it becomes leafless or nearly so for a short time during the cold season, the leaves turning red before falling; the new bright green leaves appear from January to March (northern India). The much-branched terminal panicles of minute flowers, which are unisexual and usually dioecious, appear from March to May. The fruits, in lax pendulous clusters, ripen from December to February. The tree sometimes fruits in great abundance, particularly in somewhat dry localities. The fruit (Fig. 305, *a*) is a brown 3- or 4-seeded globose berry 0.3–0.4 in. in diameter. The seeds (Fig. 305, *b*) are 0.15 in. long, trigonous with one rounded and two flat sides, light brown, smooth, with a hard testa and a thin papery albumen. About 2,600 seeds weigh 1 oz. Tests carried out at Dehra Dun showed a fertility of 50 per cent. for fresh seed, but seed kept for one year failed to germinate.

GERMINATION (Fig. 305, *c-h*). Epigeous. The radicle emerges from one end of the seed and quickly descends. The hypocotyl elongates by arching, and in straightening carries above ground the cotyledons enclosed in the testa and the thin albumen, which ultimately fall to the ground with the expansion of the cotyledons.

THE SEEDLING (Fig. 305).

Roots: primary root long, moderately thick, terete, tapering, whitish to light brown; lateral roots numerous, long, fine, fibrous, distributed down main root. **Hypocotyl** distinct from the root, 0.7–1 in. long, obscurely quadrangular, green, glabrous. **Cotyledons:** petiole 0.1 in. long or less, flattened, channelled above, glabrous; lamina 0.6–0.7 in. by 0.5–0.6 in., foliaceous, broadly elliptical or elliptical ovate or orbicular, entire, glabrous, venation pinnate reticulate. **Stem** erect, quadrangular, green or reddish, glabrous; internodes 0.2–0.5 in. long. **Leaves** alternate, at first several simple leaves, subsequent leaves trifoliate. Stipules up to 0.3 in. long, linear acuminate, slightly falcate, caducous. Simple leaves with petiole 0.4–2 in. long, channelled above, glabrous, lamina 0.9–4.5 in. by 0.8–3 in., elliptical or elliptical ovate, serrate to crenate, apex acute or acuminate, base acute or obtuse, sub-coriaceous, glabrous, shining, venation arched, lateral veins 3–7 pairs, young leaves light green, turning darker later.

The seedling develops satisfactorily only in very moist ground. Numerous experiments carried out at Dehra Dun have shown that shade is less essential than abundant moisture; in fact the best development has been secured in plots fully exposed to the sun, provided the soil is kept well saturated. If the soil is only moderately moist then shade is essential, otherwise germination fails, or if it does take place the seedlings speedily die of drought. Loose soil favours development. Young plants commence their new growth rather early in the season (February in Dehra Dun), and in frosty localities the young shoots are apt to be injured by late frosts. The seedlings are able to struggle through grass and weeds, but their development is hindered thereby; they are capable of standing a fair amount of shade. The following measurements in experimental plots at Dehra Dun give some indication of the rate of growth of seedlings under different conditions:

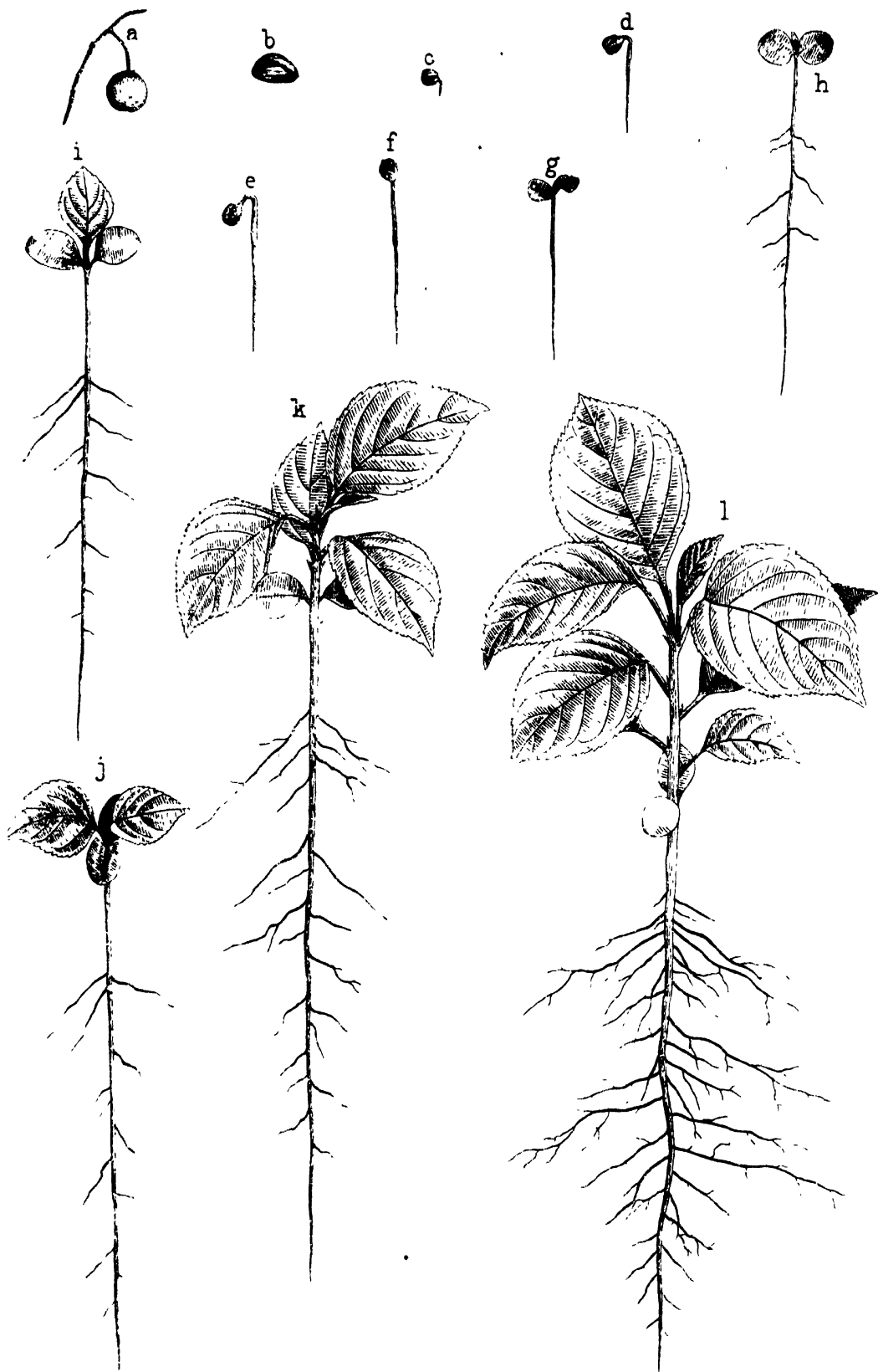


FIG. 305. *Bischofia javanica*. Seedling.
a, fruit $\times \frac{1}{2}$; b, seed $\times 2$; c-h, germination stages $\times \frac{1}{2}$; j-l, development of seedling to end of first season $\times \frac{1}{2}$.

Bischoffia javanica : growth of seedlings, Dehra Dun.

Condition under which grown.	Height at end of season.		
	1st season.	2nd season.	3rd season.
Nursery plants, moderate shade and moisture	Maximum 1 ft. 2 in.	..	..
Natural conditions, shade, not very moist	0 ft. 2 in.-0 ft. 6 in.	..	..
Natural conditions, very moist, sunny, seed fallen on bare ground	0 ft. 3 in.-2 ft. 0 in.	..	Maximum 8 ft. 3 in.
Natural conditions, very moist, sunny, seed fallen in grass	0 ft. 3 in.-0 ft. 6 in.	..	..
Natural conditions, very moist, moderate shade, seed fallen on bare ground	0 ft. 4 in. and 0 ft. 8 in.	..	..
Natural conditions, very moist, moderate shade, seed fallen on grassy ground	0 ft. 3 in.-1 ft. 3 in.	..	..
Nursery-raised transplants	Maximum 1 ft. 0 in.	1 ft. 3 in.-3 ft. 0 in.	1 ft. 9 in.-5 ft. 11 in.

SILVICULTURAL CHARACTERS. The tree stands moderate shade. It thrives best in moist and even wet situations, though it is capable of growing on comparatively dry ground, provided it is watered in the earlier stages of its life. It resists ordinary frosts, but in the severe frost of 1905 it suffered severely in the sub-Himalayan tract. It has good coppicing power, producing vigorous shoots in abundance.

NATURAL REPRODUCTION. Numerous experimental plots were laid out at Dehra Dun to ascertain the conditions which favour natural reproduction. It was found that under natural conditions the seed germinated in very moist ground or under shade from April onwards, germination continuing into the rainy season. No germination was ever found to take place on dry ground in the sun, while if, as sometimes happened, seed germinated on dry ground under shade owing to the occurrence of heavy rain during the hot season, the seedlings invariably died of drought in the subsequent dry weather preceding the monsoon. On ground kept constantly saturated seed was found to germinate freely both in the shade and in the sun, the seedlings surviving in either case, though they died off under heavy shade. It was found to be of great advantage if the seed became covered with earth before germination, the percentage of success being considerably higher than in the case of seed germinating on the surface of the ground; in the alluvial or swampy ground on which this species thrives it is probably customary for much of the seed to become covered before it germinates. Bare loose ground also favours natural reproduction. In April seed was scattered evenly over two plots side by side, one with bare soil recently dug up and levelled and the other on grass-covered ground; both plots were exposed to the sun, and in either case the soil was kept constantly saturated. By the end of the year the plot with bare soil contained 78 seedlings 3 to 24 inches in height, while the grass-covered plot contained six seedlings 3 to 6 inches in height; by that time both plots were covered with grass. Next June the former plot contained a vigorous crop of plants up to 4 ft. 7 in. in height, while there were no surviving seedlings in the latter. The beneficial results of bare loose ground are probably due partly to the fact that the covering of the seed is facilitated, partly to the absence of competition with weeds during the early life of the seedlings; in the experi-

mental plots in question, also, the development of the seedlings in the originally bare plot was no doubt greatly stimulated by the aeration of the soil owing to its having been dug up.

ARTIFICIAL REPRODUCTION. Experiments at Dehra Dun have shown that direct sowing cannot always be relied on, though it has proved successful on saturated ground. Transplanting from the nursery proved quite successful. The best results were obtained by sowing the seed in porous soil in boxes kept under shade and copiously watered. Good results were also obtained by sowing in March in nursery beds of porous soil well dug up, the drills being about 9 inches apart, and the seed being lightly covered; germination began in two to three weeks, and continued for some time. It was found necessary to keep the beds shaded and to water them regularly and copiously, the soil being frequently loosened. Until the seedlings appeared above ground it was also found advantageous to cover the beds with straw in order to retain the moisture in the soil. The seedlings were transplanted without difficulty and with complete success during the first rainy season.

RATE OF GROWTH. The growth is fast, sometimes, according to Gamble, as fast as 4 rings per inch of radius, representing a mean annual girth increment of 1.57 in.

3. BRIDELIA, Willd.

About twelve Indian species of trees, shrubs, and climbers. The commonest and best known tree is *B. retusa*, Spreng., the other tree species being somewhat local. *B. stipularis*, Bl., is a common climber in the sub-Himalayan tract from the Ganges eastward and in various parts of the Indian Peninsula and Burma.

Bridelia retusa, Spreng. Syn. *Cluytia spinosa*, Willd. Vern. *Kaj*, *khaja*, *karka*, *kassi*, Hind.; *Asana*, *kutki*, Mar.; *Muljane*, Kan.; *Koramadi*, Tel.; *Mullu-maruthu*, Tam.; *Seikchi*, Burm.

A moderate-sized or large deciduous tree with variable coriaceous leaves with straight parallel lateral veins. Bark grey to dark brown, longitudinally cracked. Young trees often have the stems covered with strong spines. Wood grey to olive-brown, durable, used for house-posts, carts, cart-shafts, and agricultural implements. The bark is used for tanning, and the leaves for cattle-fodder.

DISTRIBUTION AND HABITAT. Throughout the greater part of India and Burma, but not in the driest parts of India; it extends into the dry zone of Burma. This is a common tree in mixed deciduous forests, though it is not gregarious; it is a common accessory species in sal forests. In some types of lower mixed forest in Burma it is so plentiful as to be almost gregarious in patches.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The leaves are shed in the hot season, usually turning yellowish or reddish before falling; the new leaves appear about May-June, sometimes before the old ones have all fallen. The lateral clusters of small yellow monoecious or dioecious flowers appear from May to August, sometimes later, and the fruits ripen in January-February (northern India). The fruit (Fig. 306, *a*) is a globose fleshy sweetish drupe about the size of a pea, yellowish green turning purplish black when overripe,

containing one or two pyrenes with fairly thick bony shells ; about 450-500 pyrenes weigh 1 oz. Seed tested at Dehra Dun showed 75 per cent. of fertility. The seeds have a brownish papery testa. The fruits are greedily eaten by birds, especially green pigeons and also parrots and hornbills, and the seeds are spread by their agency.

GERMINATION (Fig. 306, *b-e*). Epigeous. The shell of the pyrene splits, the radicle emerging. The hypocotyl elongates by arching, and in straightening raises above ground the cotyledons enclosed in the testa, which falls to the ground with the expansion of the cotyledons.

THE SEEDLING (Fig. 306).

Roots : primary root moderately long and thick, terete, tapering ; lateral roots moderate in number, long, fibrous. *Hypocotyl* distinct from root, 0.5-0.8 in. long, terete, tapering slightly upwards, pubescent. *Cotyledons* : petiole 0.05 in. long, pubescent ; lamina 0.3-0.4 in. by 0.4-0.5 in., foliaceous, broadly obovate or sub-orbicular, apex truncate or emarginate, base obtuse or acute, entire, minutely pubescent. *Stem* erect, terete, wiry, pubescent ; internodes 0.2-1 in. long in first season. *Leaves* simple, alternate. Stipules about 0.1 in. long, linear falcate, acuminate. Petiole 0.05-0.15 in. long. Lamina 0.3-1.5 in. by 0.25-1 in., elliptical or obovate, apex rounded, acute or obtuse, base acute, entire or obscurely crenate, glabrous or young leaves with pubescent margins, green above, glaucous beneath, venation pinnate, lateral veins 6-13 pairs.

The growth of the seedling is somewhat slow, a height of 3-6 in. being ordinarily attained in the first season in the case of nursery plants. Natural seedlings in the forest were found to reach a height of only 2-3 in. in the first season. By the end of the second season a height of 6-20 in. may be attained. At Dehra Dun the leaves of seedlings turn yellow and fall about December to February, new growth commencing in February-March. Natural seedlings with their leaves still present were found in February in Singhbhum, Chota Nagpur, and the early fall of the leaves at Dehra Dun is no doubt attributable to cold. The seedlings are somewhat sensitive to frost. They stand moderate shade well, but under heavy shade they may die off in a single season. They have good power of struggling through a moderate growth of grass and weeds, but their development is much impeded thereby.

SILVICULTURAL CHARACTERS. The tree stands moderate but not heavy shade. Its leaves are somewhat readily touched by frost, but it has good power of resisting permanent injury, and is often found as one among comparatively few survivors on grassy areas subject to frost. In the abnormal drought of 1907 and 1908 in the forests of Oudh it proved to be decidedly hardy. It coppices well, and produces root-suckers.

NATURAL REPRODUCTION. As already mentioned, the seed is spread by green pigeons and other birds. Some of it, however, falls round the parent trees and germinates there, the fleshy portion of the fruit drying up or becoming consumed by insects. Much of the seed is destroyed by rats, which break open the hard pyrenes. Under natural conditions germination commences early in the rainy season and continues to some extent throughout that season. Germination is favoured if the seed becomes buried during the early showers preceding the rainy season, or if it lies under moderate shade ; seed lying on the surface of the ground exposed to the sun as a rule fails to germinate successfully.

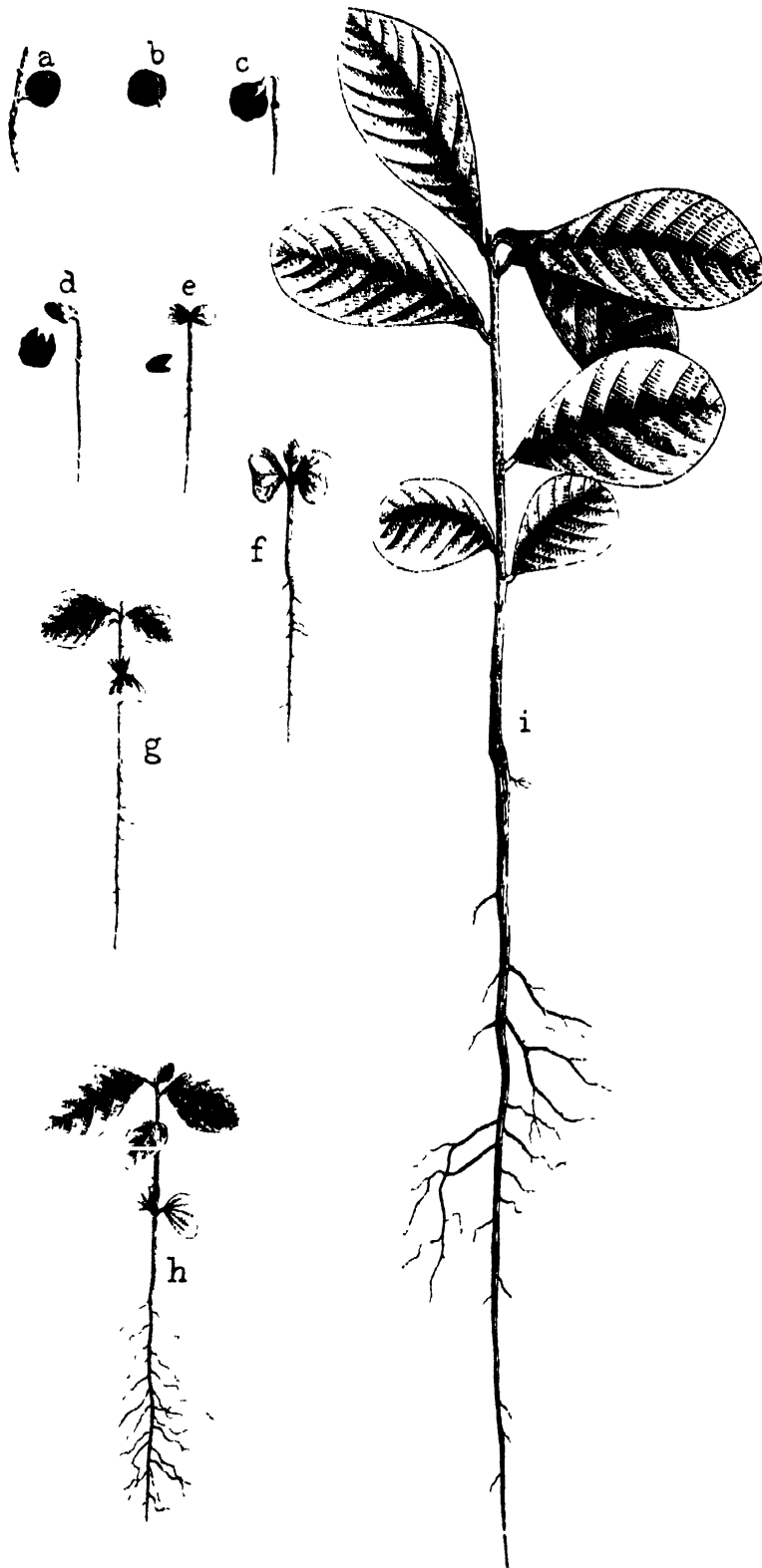


FIG. 306. *Bridelia retusa*. Seedling $\times \frac{1}{2}$.

a, fruit ; *b-e*, germination stages ; *f-h*, development of seedling during first season ; *i*, seedling towards close of second season.

ARTIFICIAL REPRODUCTION. Seedlings can be most successfully raised in the nursery if the beds are kept shaded from the sun in the heat of the day and regularly watered. The seed should be sown about March, and the seedlings can be transplanted without much difficulty during the first rainy season. Transplanting in the second rains requires more care owing to the length of the taproot. Direct sowings have not been tried.

RATE OF GROWTH. The following girth increments have been obtained in periodically measured high forest sample plots in sal forest :

Bridelia retusa : girth increments in high forest sample plots.

Province.	Forest division.	Locality.	Number of trees under measurement.	Girth classes. ft.	Mean annual girth increment (period not stated). in.
United Provinces	Lansdowne	Giwain	1	..	0.31
Central Provinces	Balaghat	Raigarh and Baihar ranges	3 1	1-2 3-4	0.15 0.47

A cross-section in the silvicultural museum at Dehra Dun showed 96 rings for a girth of 5 ft., giving a mean annual girth increment of 0.62 in. Gamble gives the growth at about 5 to 6 rings per inch of radius, representing a mean annual girth increment of 1.05 to 1.26 in.

Coppice growth is fairly fast. Measurements of coppice-shoots one year old in the Bhandara district, Central Provinces, in 1912-13, gave a mean height of 6 ft. 9 in. for *Bridelia*, as compared with 7 ft. 1 in. for teak and 6 ft. 6 in. for *Terminalia tomentosa*. The following are the results of measurements made in 1911 in young coppice coupes in the Tikri forest, Gonda, United Provinces, the growth of *Bridelia* and sal being compared :

Bridelia retusa : coppice measurements, Gonda.

Age. years.	Mean height.		Average number of shoots per stool.	
	<i>Bridelia retusa</i> . ft.	Sal. ft.	<i>Bridelia retusa</i> .	Sal.
1	4.3	4.7	3	2.2
2	9.9	10.0	2.7	1.7
2	6.3	7.6	2	1.8

The following are the results of coppice measurements made in 1910 by Mr. C. M. McCrie in the Gorakhpur district, United Provinces :

Bridelia retusa : coppice measurements, Gorakhpur.

Age. years.	Mean height.		Mean girth.	
	<i>Bridelia retusa</i> . ft.	Sal. ft.	<i>Bridelia retusa</i> . in.	Sal. in.
2	3.0	3.0	—	..
4	6.7	7.0	1.7	2.0
6	9.6	10.3	2.7	2.9
8	12.0	13.0	3.7	3.8
10	14.2	15.3	4.7	4.8
12	16.2	17.5	5.7	5.8
14	17.8	19.2	6.6	6.7
16	19.0	20.9	7.5	7.5

4. PUTRANJIVA, Wall.

Putranjiva Roxburghii, Wall. Vern. *Jiaputa*, *putrajiva*, Hind. ; *Putājan*, Pb. ; *Karupale*, Tam. ; *Kuduru*, Tel. ; *Taukyat*, *badibyu*, *egayit*, Burm.

A moderate-sized graceful evergreen tree with drooping branches and glossy leaves with wavy margins. Bark grey, somewhat smooth, studded with lenticels, green inside. Wood close-grained, used for turning.

DISTRIBUTION AND HABITAT. Sub-Himalayan tract from the Ravi eastwards, Indian Peninsula and Burma, usually on alluvial ground along rivers, or in swamps or evergreen forests, but occasionally met with in rather stunted form in drier situations. Along rivers and in swamp forests in the sub-Himalayan tract it is sometimes gregarious. It is not infrequently planted for ornament, and requires a fairly moist fertile soil.

FLOWERING AND FRUITING. The flowers, which are dioecious, appear with the new leaves from March to May, the small yellow male flowers in axillary heads or short spikes and the green female flowers solitary or a few together. The fruit (Fig. 307, *a, b*), which ripens in January and February (northern India), is an ellipsoidal, obovoid, or nearly globose light grey tomentose drupe, 0.5–0.6 in. long, with a very hard pale yellow putamen almost filling it ; the seed has a copious white albumen. About 40–50 fruit-stones weigh 1 oz. The drupe is normally 1-seeded, but is occasionally 2-seeded. The fruits are eaten by deer, the hard stones being disgorged during rumination and the seed being thus disseminated. The germinative power of the seed is somewhat uncertain ; fertility is retained to some extent, however, for at least a year, tests with seeds one year old having shown 23 per cent. of success.

GERMINATION (Fig. 307, *c-h*). Epigeous. The hard putamen dehisces and the radicle emerges from one end of the fruit-stone, descending and forming a taproot of some length before any upward growth takes place. The hypocotyl then elongates by arching, withdraws the cotyledons from within the putamen, and in straightening raises them above ground enclosed in the white albumen, which eventually falls to the ground as the cotyledons expand. Sometimes two seedlings appear from one fruit.

THE SEEDLING (Fig. 307).

Roots : primary root long, moderately thick, terete, tapering, whitish ; lateral roots numerous, moderately long, fibrous, distributed down main root. **Hypocotyl** distinct from the root, 1.4–2.2 in. long, terete, fusiform or tapering upwards, yellow turning green, minutely tomentose. **Cotyledons** : petiole 0.1 in. long or less, minutely tomentose ; lamina 0.8–1 in. by 0.6–0.8 in., foliaceous, cordate, entire, apex rounded, glabrous, 5-veined from the base, the central three veins more distinct than the lateral two ; the cotyledons persist through part of the second season. **Stem** erect, terete, wiry, green, minutely pubescent ; internodes 0.3–0.8 in. long. **Leaves** simple, alternate. **Stipules** minute, subulate, deciduous. **Petiole** 0.1–0.2 in. long, pubescent. **Lamina** 1.2–2.2 in. by 0.5–0.7 in., elliptical lanceolate, acute or acuminate, sharply serrate, bright green, shining, glabrous or with minute scattered hairs on lower surface.

The growth of the seedling is slow, a height of only 1 to 6 in. being attained by the end of the first season. Plants raised at Dehra Dun and kept regularly weeded and watered attained a height of 9 in., 4 ft., and 6 ft. by the end of the

second, third, and fourth seasons respectively ; under natural conditions the growth is probably slower. The seedling commences to form long side branches from about the second year. Young plants stand moderate shade, but become

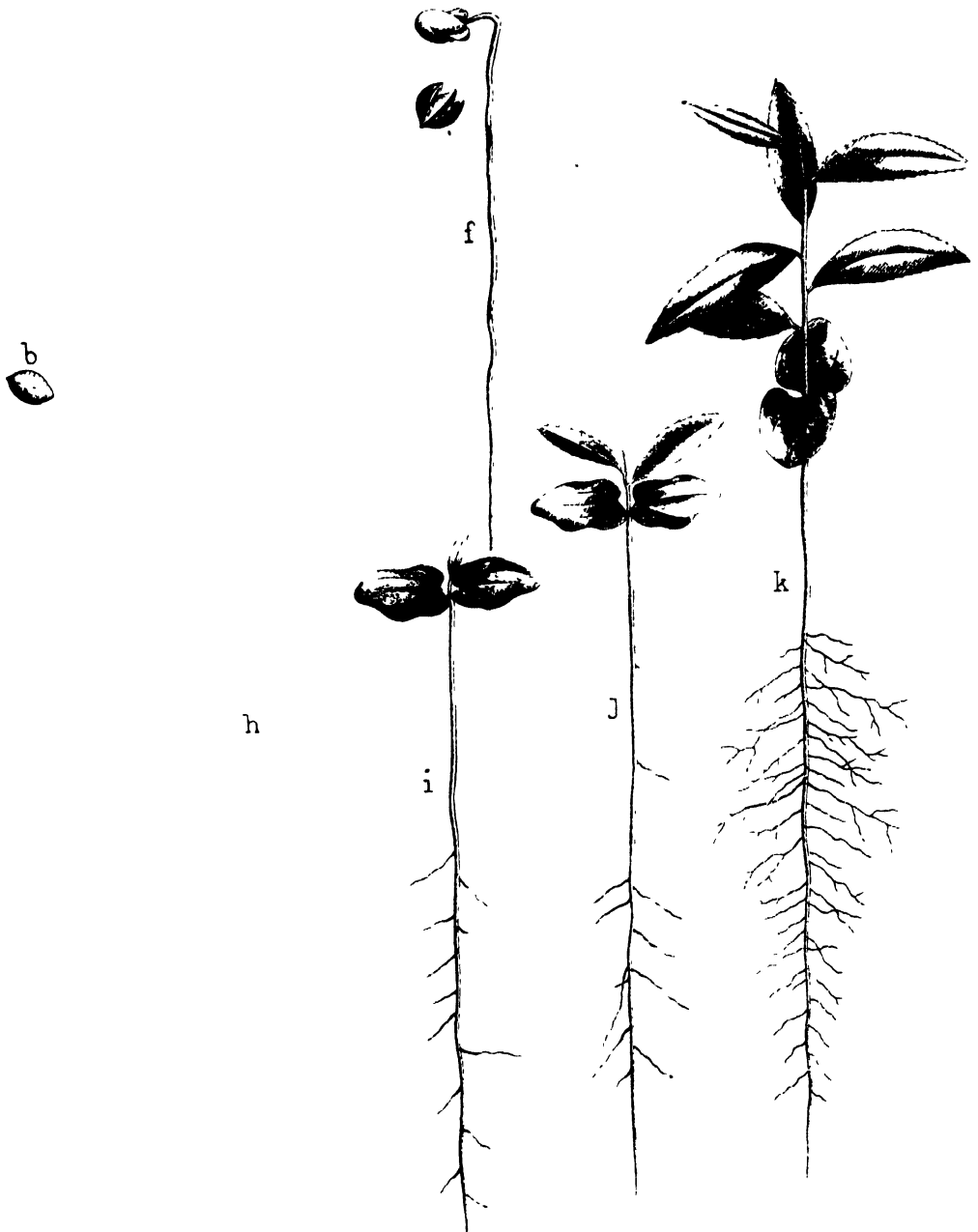


FIG. 307. *Putranjiva Roxburghii*. Seedling $\times \frac{1}{2}$.

a, fruit ; b, endocarp ; c-h, germination stages ; i-k, development of seedling during first season.

suppressed and die off in dense shade ; they are sensitive to frost and drought, particularly in the first two years. During and soon after germination the seedlings suffer from the attacks of crickets.

NATURAL REPRODUCTION. The fruits fall during the early part of the hot season. They are often deprived of their fleshy covering by deer, and the light yellow fruit-stones may be found lying where these animals have ruminated. Fruits which lie on the ground for some time often become deprived of their fleshy covering by white ants. Many of the fruits become wholly or partially buried by the action of rain, and this is of great advantage, since if the seed germinates on the surface of the ground the germinating seedling is apt to perish from drought before the root penetrates the soil. Germination takes place at various times during the rainy season, and numerous seedlings may often be found around and beneath the parent trees.

ARTIFICIAL REPRODUCTION. The fruit-stones should be sown in nursery-beds about April and lightly covered with earth, the beds being kept regularly watered and weeded. Germination takes place in six weeks to six months. Frosty localities should be avoided, but if frost is to be feared the seedlings should be protected during the first winter by a covering of thatch. The more vigorous plants will be ready for planting out the following year, when about a year old, while the less vigorous ones should be kept for another year in the nursery. Transplanting should be carried out during the rainy season, and the seedlings stand it well, provided care is taken not to injure the taproot, which is often of some considerable length.

5. PHYLLANTHUS, Linn.

A large genus of herbs, trees, or shrubs, mostly of little importance. *P. reticulatus*, Poir., is a large straggling or climbing shrub, common in many of the drier parts of India and Burma, especially on low moist ground near streams; it occurs in the riverain forests along the Indus in Sind. By far the commonest tree of this genus is the following:

Phyllanthus Emblica, Linn. Syn. *Cicca Emblica*, Kurz; *Emblica officinalis*, Gaertn. Vern. *Aonla*, *amla*, *amlaka*, Hind.; *Aml*, Pb.; *Amluki*, Ass.; *Nelli*, Tam.; *Usiriki*, Tel.; *Zibyu*, *tasha*, Burm. (Fig. 304.)

A moderate-sized deciduous tree with feathery light green foliage and small narrow linear leaves. Bark smooth, grey, exfoliating in irregular rounded scales, exposing the young yellow bark beneath; there is a distinct chlorophyll layer immediately below the surface, beneath which is the soft red astringent cortex. Wood red, hard, apt to split, durable under water, used for agricultural implements, well-construction, and inferior building and furniture. The bark, leaves, and fruits are used for tanning, and the tree promises to become important as a yielder of tannin.

DISTRIBUTION AND HABITAT. Common in mixed deciduous forests throughout the greater part of India and Burma, ascending the Himalaya to 4,500 ft. Not common west of the Ravi, and not found in the arid regions.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The leaves commence falling about November or December, and the trees are leafless from about February or March to March or April, when the new shoots appear. The twigs are frequently deciduous, falling with the leaves attached, the whole resembling compound pinnate leaves. The minute yellowish flowers, densely fascicled in the axils of the young leaves, appear from March to May, and are visited by swarms of bees. The fruits (Fig. 308, *a*), which ripen from November



FIG. 308. *Phyllanthus Emblica*—SEEDLING $\times \frac{3}{4}$

Fruit b Hard endocarp c Endocarp splitting d Seed e-h—Germination stages
 i-k—Development of seedling during first season

to February or sometimes later, are 0.5–0.8 in. in diameter, globose, yellowish green, smooth, fleshy, and very astringent, with a 6-ridged bony endocarp (Fig. 308, *b*, *c*) containing about four to six dark brown smooth 3-gonous seeds (Fig. 308, *d*), of which about 1,800 to 1,900 weigh 1 oz. The seeds may be extracted by placing the ripe fruits in the sun until the hard putamen dehiscens and the seeds escape. Tests at Dehra Dun showed that the percentage of fertility is comparatively low, and that the seed does not retain its vitality long, seed kept for a year having failed to germinate.

GERMINATION (Fig. 308, *e–h*). Epigeous. The radicle emerges from the end of the seed and descends. The hypocotyl elongates by arching, and in straightening carries the cotyledons above ground. The testa is carried up over the cotyledons, falling with their expansion or frequently clinging for a time to the apex of one of them after they expand.

THE SEEDLING (Fig. 308).

Roots : primary root long, wiry, flexuose ; lateral roots numerous, fibrous, distributed down main root. **Hypocotyl** distinct from root, 0.8–1 in. long, tapering upwards, pink or green turning light brown, glabrous or very finely pubescent in upper part. **Cotyledons** : petiole 0.04 in. long ; lamina 0.4–0.6 in. by 0.2–0.3 in., elliptical or oblong, apex rounded, entire, foliaceous, green, glabrous. **Stem** erect, terete, wiry, reddish brown, minutely pubescent. **Leaves**, first 2–6 sub-opposite or alternate, very shortly petiolate, situated singly on main stem, 0.4–0.5 in. by 0.15–0.25 in., oblong, entire, mucronate, glabrescent or minutely pubescent ; subsequent leaves distichously arranged on finely pubescent branchlets, sub-sessile, 0.2–0.4 in. by 0.05–0.1 in., linear oblong, entire, minutely mucronate, glabrous ; stipules 0.04 in. long, linear falcate.

Under favourable conditions the growth of the seedling is rapid. At Dehra Dun seedlings on weeded but unwatered ground attained a maximum height in the first four years of 2 ft. 8 in., 7 ft., 9 ft. 7 in., and 16 ft. 6 in., the basal girth at the end of the fourth year being 7 in. Weeding greatly stimulates development, while the presence of weeds retards it, although after the seedlings have outgrown the weeds their growth is rapid. The maximum growth in unweeded plots during the first three years was 5 in., 3 ft. 8 in., and 9 ft. 10 in. Under natural conditions the growth is probably slower. The young plant is intolerant of shade or suppression of any kind, and when several young plants grow together one or two vigorous specimens quickly tend to take the lead and to suppress the remainder. In the first few months the seedlings are somewhat delicate ; they are sensitive to drought, are apt to be washed away or beaten down by heavy rain, and are much subject to the attacks of insects, rats, and squirrels. Although the leaves are often touched by frost before falling, young plants do not appear to suffer permanently from ordinary frosts.

SILVICULTURAL CHARACTERS. *Phyllanthus Emblica* is a decided light-demander. It is sensitive both to frost and to drought. In severe frosts the fruit becomes whitish, with the appearance of having been boiled. In the Indian Peninsula it suffered much in the abnormal drought of 1899–1900 and in the dry years preceding 1913–14 ; many trees were killed outright, while a common form of injury was the formation of large cracks down the stem, the thin bark affording little protection against the sun.

The tree coppices well and pollards moderately well ; coppice-shoots in

particular grow vigorously. An experiment was carried out in North Chanda in 1909 in which the effect of coppicing in different months from April to September was tested. The percentage of stools which coppiced successfully was as follows : April, 100 ; May, 95 ; June, 90 ; July, 100 ; August, 100 ; September, 100.

NATURAL REPRODUCTION. Under natural conditions the fruits fall during the latter part of the cold season and a portion of the hot season. They lie on the ground until the fleshy covering dries up and the hard fruit-stones split open, which they do with some force, the seeds thus escaping. Germination takes place early in the rainy season. The fruits are eaten by deer, the hard stones being disgorged during rumination and afterwards dehiscing on the ground. Natural reproduction is seldom found in any great abundance ; this is possibly due partly to the fact that the fertility of the seed is not high, but mainly perhaps to the sensitiveness of the seedling in its early stages and to its liability to insect attacks.

ARTIFICIAL REPRODUCTION. Seedlings have been raised successfully at Dehra Dun by sowing the seed in the nursery about March, watering regularly but sparingly and protecting the seedlings for the first few months from the sun and from heavy rain. If the beds are regularly weeded the seedlings should be large enough to plant out in the first rainy season, but care is necessary not to expose the roots, as the seedlings are somewhat sensitive to transplanting. Direct sowing has been tried on a small scale, but owing to the infertility of the seed gaps are apt to be frequent ; the best results were obtained by sowing at the commencement of the rainy season and subsequently weeding regularly. Tolerably well stocked lines can be ensured by thinning out congested seedlings during the first rainy season and using the surplus plants for filling up gaps.

SILVICULTURAL TREATMENT. For the production of tan-bark, which is probably the chief use to which the tree will be put in future, coppice is the system indicated, though the best rotation remains to be ascertained. The concentration of supplies of bark over a limited area can be secured only by artificial reproduction.

RATE OF GROWTH. The growth of young plants, as already noted, is fairly rapid, but subsequent growth appears to be somewhat slow. In sample plots in the Balaghat district, Central Provinces, periodic measurements of nine trees 12 to 36 in. in girth showed a mean annual girth increment of only 0.15 in.

Ring-countings by Mr. D. A. Thomson in 1905, in respect of seven trees in the Supa fuel reserves in North Kanara, gave the following results :¹

Phyllanthus Emblica : rate of growth, Supa fuel reserves.

Age. years.	Mean diameter. in.	Corresponding girth.		Age. years.	Mean diameter. in.	Corresponding girth.	
		ft.	in.			ft.	in.
5	1.05	0	3	30	6.11	1	7
10	2.12	0	6	35	7.12	1	10
15	3.06	0	9	40	8.06	2	1
20	4.11	1	1	45	8.76	2	3
25	5.10	1	4				

¹ Working Plan for the Supa Fuel Reserves, 1906.

A cross-section from the United Provinces in the silvicultural museum at Dehra Dun had 48 rings for a girth of 3 ft. 4 in., giving a mean annual girth increment of 0.83 in.

Coppice measurements made in 1910 by Mr. C. M. McCrie in the Gorakhpur district, United Provinces, gave the following results :

Phyllanthus Emblica : rate of growth of coppice, Gorakhpur.

Age.	Mean height.	Mean girth.	Age.	Mean height.	Mean girth.
years.	ft.	in.	years.	ft.	in.
2	4.7	1.4	10	12.0	4.6
4	7.7	2.6	12	12.7	5.0
6	9.6	3.5	14	13.1	5.3
8	10.9	4.2	16	13.3	5.6

Measurements of coppice-shoots one year old in the Bhandara district, Central Provinces, in 1912-13, showed an average height of 7.4 ft.

6. CLEISTANTHUS, Hook. f.

Cleistanthus collinus, Benth. Syn. *Lebidieropsis orbicularis*, Muell. Arg. ; *Cluytia collina*, Roxb. Vern. *Garar, garari*, C.P. ; *Korei, korshe*, Tel. ; *Wodan*, Tam.

A small tree with orbicular obovate or broadly elliptical leaves, glaucous beneath. Bark dark brown, almost black, rough, exfoliating in small woody rectangular scales, red inside. Wood dark reddish brown, hard, durable, much used for house and fence posts.

DISTRIBUTION AND HABITAT. Common in many parts of the Indian Peninsula as far north as the Ganges river and Chota Nagpur, especially in the Singhbhum district. It is one of the commonest trees in some of the dry types of mixed forest, and thrives on dry rocky ground, where it often becomes more or less gregarious. In the Alapilli forest of South Chanda it attains 6 ft. in girth. In the Central Provinces it is frequently found on laterite, where it flourishes, particularly where the rock is decomposing.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The tree is leafless in March-April. The small greenish flowers appear with the new leaves in April-May, sometimes also in September (Haines), and the fruits ripen the following March-April. The fruit is a globose, 3-valved, 3-seeded capsule, brown, shining, and woody when ripe, bursting open with an audible crack in the hot weather and scattering the seeds.

SILVICULTURAL CHARACTERS. The tree is very hardy and survives fire and grazing better than almost any other species ; it is seldom browsed, and is said to be poisonous, on which account it is often the commonest species on grazed areas. Although it thrives in dry localities it suffered considerably in the abnormal drought of 1899-1900 in the Central Provinces. It produces root-suckers and coppices very well, though it often takes some time for one shoot to develop separately into a pole from the mass of shoots produced from the stool.

ARTIFICIAL REPRODUCTION. The tree has been raised with success with the aid of field crops in Berar ; vide C. G. Rogers's note in *Indian Forester*, vol. xxxvii (1911), p. 8.

RATE OF GROWTH. Measurements made in 1916 in the Saitba coppice coupes, Kolhan, Chota Nagpur, gave the following average growth :

Cleistanthus collinus : rate of growth in coppice coupes, Saitba.

Age. years.	Mean girth. in.	Mean height. ft.	Age. years.	Mean girth. in.	Mean height. ft.
2	1.6	4.5	10	6.8	17.7
4	3.2	9.0	12	7.7	20.0
6	4.5	12.0	14	8.5	22.2
8	5.8	15.0			

Measurements of coppice-shoots one year old, made in 1912-13 in the Bhandara district, Central Provinces, showed an average height of 6 ft. 11 in. for *Cleistanthus* as against 7 ft. 1 in. for teak, 6 ft. 6 in. for *Terminalia tomentosa*, and 6 ft. 4 in. for *Acacia Catechu*. Gamble gives the average growth as six rings per inch of radius, representing a mean annual girth increment of 1.05 in.

7. BUXUS, Linn.

Evergreen shrubs or trees with opposite coriaceous leaves. There are two distinct forms in India, the habits of which differ greatly. Brandis (*Indian Trees*) describes one species only, *B. sempervirens*, Linn., which is also the European species. Parker (*Forest Flora of the Punjab*) describes two separate species, *B. Wallichiana*, Baill., and *B. papillosa*, C. K. Schn. The habits of the two forms are so divergent that it will be necessary for our purpose to consider them separately. *B. Wallichiana* has leaves shining above, pale green beneath, the horns of the capsule spreading ; it grows in moist situations at elevations of 4,000 ft. and upwards. *B. papillosa* has leaves dull green above, pale or whitish beneath, longer and narrower than those of *B. Wallichiana*, the horns of the capsule erect ; it grows in dry situations below 4,000 ft., and if not a separate species, is at all events a marked xerophytic form of *B. Wallichiana* or *B. sempervirens*.

Species 1. *B. Wallichiana*, Baill. ; 2. *B. papillosa*, Schn.

1. **BUXUS Wallichiana**, Baill. Syn. *B. sempervirens*, Linn. (in part). Box, boxwood. Vern. *Papri*, *shamshad*, *sansád*, *chikri*, W. Him.

An evergreen shrub or small tree with opposite coriaceous shining leaves, 1 to 2, or occasionally 3 in. long. Bark yellowish grey, corky, soft, cut into numerous small rectangular plates on old stems. Wood yellowish white, hard, very close and even grained, used for engraving, turning, carving, mathematical instruments, &c. In India it is much used for the manufacture of combs. Boxwood, which commands a high price, is well known in European markets. In unfavourable situations the box is a mere shrub, but under favourable conditions it reaches fair dimensions. Mr. Beadon Bryant, in his report on the boxwood forests of Kumaun and British Garhwal,¹ says he measured one tree with a girth of 86 in. at 5 ft. from the ground, and trees of 5 ft. in girth with a trunk of 25 ft. to the first branch and a total height of 40 to 50 ft. were often to be found ; many of the larger trees, however, were unsound, and the best size to cut he considers to be from 2 to 4 ft. in girth.

DISTRIBUTION AND HABITAT. In India the tree is found in the Western Himalaya, extending eastward to Nepal at elevations from 4,000 to 9,000 ft. ;

¹ Ind. Forester, xi (1885), p. 283.

also in Bhutan. Its occurrence in the Punjab and the United Provinces has been the subject of reports by Messrs. B. Ribbentrop¹ and F. Beadon Bryant,² and from these reports it would appear that its distribution is very local and not always easy to explain. In the Punjab Himalaya it occurs locally in Bashahr at 6,000 to 8,000 ft., in Kulu at about 7,500 ft., and in Chamba at about 6,500 ft. In 1885 Ribbentrop estimated the total area of boxwood in the Punjab at 1,387 acres, of which only a very small area contained pure box; this estimate included *B. papillosa*. The number of mature trees above 2 ft. in girth amounted to 7,047 in Bashahr, 520 in Kulu, and 140 in Chamba. Since these enumerations were made a considerable amount of boxwood appears to have been extracted from Bashahr, but the cost of extraction proved to be prohibitive.

In the United Provinces the tree occurs in Jaunsar, chiefly at about 7,000 ft., in Tehri Garhwal at about 8,000 ft., and in Kumaun and Garhwal at 7,000 to 9,000 ft., where, according to Mr. Bryant, it is rarely found far from the snowy range; and when quite close to the snows, although often plentiful, it is badly grown and of little value, probably owing to the heavy snowfall. He estimated the total number of trees in Kumaun and Garhwal in 1885 at 25,000, and on the assumption that a tree is fit to cut at eighty years, the annual outturn was estimated at 300 trees, giving, at an average of 3 cubic ft. per tree, 900 cubic ft.

In 1883 Mr. Hearle³ noted that on the Jumna box forests probably occurred at one time in a continuous belt for 20 miles from Kotnur to Kharsali, the last village before the snows are reached, but only small isolated patches then remained, the rest having been cleared for cultivation. The elevation varied from 4,000 to 8,000 ft., but most of the box was found in a narrow belt along the lower edge of the forest between 6,000 and 7,000 ft.

In Bashahr the box occurs on shale and gneiss, in Chamba on mica schist, and in the Jumna valley on gneiss and mica schist. The essential conditions for its successful growth appear to be moisture and shelter, for it is characteristically found in moist sheltered ravines, and along the banks of perennial streams. It avoids hot aspects, and seeks northerly and north-westerly slopes. Although found pure or nearly so in patches, which may extend to several acres in area, it is frequently found associated with other species, such as oaks, maples, horse-chestnut, yew, walnut, holly, alder, spruce, &c., while on rich soil there is often a dense undergrowth of ferns, shrubs, and dwarf bamboo.

SILVICULTURAL CHARACTERS, &c. The tree is a shade-bearer, and often grows under a canopy of other species. If the shade is too dense, however, it becomes suppressed and the growth suffers. The leaves are poisonous to cattle, though goats eat them sparingly with impunity (Gamble). The tree regenerates freely in moist sheltered situations, but not in exposed places; seedlings often establish themselves under the shelter of rocks. The flowers, which are monoecious, appear from March to May, and the fruits ripen from June to August. The capsule is 0.4 to 0.5 in. long, broadly ovoid, 3-valved, with spreading horns, and the seeds are 0.25 in. long, 3-angled, oblong, with a black shining testa.

¹ Ind. Forester, xi (1885), p. 25.

² *Ibid.*, p. 283.

³ *Ibid.*, ix (1883), p. 196.

ARTIFICIAL REPRODUCTION. The tree reproduces well from cuttings; Gamble mentions that it is extensively raised in this way for hedges in the Government cinchona estates on the Nilgiris, and suggests planting box for profit on northern aspects in those hills, where the nearness to the coast would make the sale of the wood more profitable than it is in the remoteness of the Himalaya.

According to Mian Moti Singh,¹ attempts to raise the tree from seed in nurseries in Bashahr had up to the time of writing always failed. This he attributes to the fact that the seed had been extracted from the capsules before sowing, and was therefore destroyed by frost; on the other hand, a quantity of capsules left in the corner of a field produced a dense crop of seedlings. He recommends sowing entire capsules, when thoroughly ripe, early in the rainy season. Possibly success might be attained by sheltering the nursery beds sufficiently, even if seeds are extracted from the capsules before sowing.

RATE OF GROWTH. The rate of growth is very slow. Gamble's specimens showed 14 (from the Shali hill) to 75 (from Kunawar) rings per inch of radius, and averaged $33\frac{1}{2}$ rings. This represents a mean annual girth increment varying from 0.084 to 0.45 in. and averaging about 0.18 in. Taking 20 rings per inch as the rate, a diameter of 1 ft. would be reached in 120 years, which, as Gamble mentions, is probably a minimum. Brandis gives 15 to 20 rings per inch of radius, or a mean annual girth increment of 0.31 to 0.42 inch.

Ribbentrop gives the following results of ring-countings in different parts of the Punjab:

Buxus Wallichiana: rate of growth, Punjab.

Locality.	Average number of rings per inch.	Mean annual girth increment.	Approximate number of years required to attain a workable size of 2 ft. girth.
Bashahr . . .	18	0.35	70
Chamba . . .	28	0.22	110
Kulu . . .	30	0.21	115

2. *Buxus papillosa*, C. K. Schn. Syn. *B. sempervirens*, Linn. (in part). Vern. *Shamshád*, Pb.

A large evergreen shrub or small tree with a crooked stem. Leaves usually 1.5–3 in. long, dull green above, whitish papillose beneath. Wood similar to that of *B. Wallichiana*, but the tree only grows to a small size, and the wood is used only for fuel.

This species grows on the dry and arid slopes of the outer Himalaya from the Jhelum westwards at 2,000 to 4,000 ft., the Salt Range, trans-Indus, the Kalachitta and Margalla forests of the Rawalpindi district, and the Garamthun reserve in Hazara. It is found usually on dry limestone hills; in the Shahpur Salt Range it occurs on sandstone. It is cultivated at Lahore. Natural reproduction is usually reported to be poor; the seedlings appear to require the shelter of bushes and rocks, and to benefit by the presence of pockets of soil with a certain amount of moisture. The flowers appear from December to February, and the fruits ripen from June to August (?); in the Rawalpindi

¹ Ind. Forester, xxi (1895), p. 89.

district I have found fruits in May full-sized but not quite ripe. The capsules are 0.4 to 0.5 in. long, ovoid, with erect horns. The plant can be propagated from cuttings. Ribbentrop found the average number of rings per inch of radius to be 30 to 40, giving a mean annual girth increment of 0.15 to 0.21 in.

8. BACCAUREA, Lour.

Baccaurea sapida, Muell. Arg. Vern. *Latqua*, Beng. ; *Leteku*, Ass. ; *Kanazo*, Burm.

A moderate-sized evergreen tree with a round shady crown and grey, somewhat rough and corky bark. The tree is found in the eastern sub-Himalayan tract and lower hills, Assam, Chittagong, Burma, and the Andamans, chiefly in moist tropical forests. It is often cultivated for the sake of its edible fruits, which ripen early in the rainy season. The fruits, which grow in clusters, are yellow globose 3-seeded berries about the size of a large cherry, with a pleasant acid pulp formed by the arillus of the seeds. The tree stands shade and prefers a moist climate and a deep moist soil.

9. MALLOTUS, Lour.

Trees or shrubs, chiefly evergreen. Brandis (*Indian Trees*) enumerates 27 species, most of which are quite local.

Mallotus philippinensis, Muell. Arg. Syn. *Rottlera tinctoria*, Roxb. Vern. *Rohni*, *roini*, *raini*, *rauni*, Hind. ; *Kamila*, Pb. ; *Kapila*, Kan., Tam. ; *Tawthidin*, Burm.

A small much-branched evergreen tree with a short and often fluted bole. Bark thin, dark grey, red within. Wood hard and close grained, useful for bobbins. A dye known as *kamela*, used for dyeing silk, is obtained from the red glands on the surface of the capules. Silviculturally the tree is important as an accessory or undergrowth species owing to its great abundance in many forest tracts ; it is a useful nurse to more important species such as the sal, and is a good soil-improver.

DISTRIBUTION AND HABITAT. Sub-Himalayan tract and outer hills from the Indus eastwards, ascending occasionally to nearly 5,000 ft. into the region of *Pinus longifolia* and *Quercus incana*, Bengal, Chota Nagpur, Indian Peninsula, and Burma. This is a very common tree in sal forest and in certain types of mixed and scrub forest. Talbot says it is common and often gregarious throughout the Bombay Presidency and Sind in mixed monsoon or open thorn forest. In sal forest it is frequently gregarious as an underwood.

In grassy tracts within the sal forests it often appears in advance of the sal, helping to kill out the grass, thus removing inflammable material, and protecting the young sal from frost. Experiments in the use of *Mallotus* as an artificial nurse to sal are referred to in Vol. I, p. 105.

FLOWERING AND FRUITING. In northern India the flower-buds begin to appear about July, and the trees are in full flower in October, the male trees in particular being conspicuous at this time. The flowers are dioecious, the males in clusters of pale yellow spikes 5 to 10 in. long, and the females in spikes 2 to 3 in. long. The fruits, which ripen from March to May, or June at the higher elevations, are 3-lobed capsules, 0.3 to 0.5 in. in diameter, densely



FIG. 309. *Mallotus philippinensis*. Seedling $\times \frac{1}{4}$.
 a, seed ; b-f, germination stages ; g-i, development of seedling during first season.

covered with red glands. The seeds (Fig. 309, *a*) are about 0.15 in. in diameter, globose, black, smooth, with a moderately thick brittle testa; about 600 to 700 weigh 1 oz. Tests at Dehra Dun showed that the seed is rather uncertain in germinative power, and that it does not retain its fertility long.

GERMINATION (Fig. 309, *b-f*). Epigeous. Shortly after the emergence of the radicle the hypocotyl elongates by arching, and in straightening carries above ground the cotyledons, usually enclosed in the testa, which afterwards falls off with the expansion of the cotyledons.

THE SEEDLING (Fig. 309).

Roots: primary root long, moderately thick, terete, tapering; lateral roots fairly numerous, fibrous, chiefly on upper part of main root. **Hypocotyl** distinct from the root, 2-2.5 in. long, terete, tapering slightly upwards, white turning green, tomentose. **Cotyledons**: petiole 0.3-0.4 in. long, tomentose; lamina 0.4-0.5 in. by 0.4-0.6 in., foliaceous, irregularly orbicular and usually broader than long, apex rounded or truncate, base often slightly tapering, entire or irregularly undulate, green, glabrous, with a fringe of minute hairs round the margin, 5-veined from the base. **Stem** erect, terete, woody, green, tomentose, internodes 0.2-0.5 in. long. **Leaves** simple, alternate, exstipulate. Petiole 0.3-1.8 in. long, terete, pubescent. Lamina 0.7-4 in. by 0.5-2.8 in., the earlier leaves small, ovate, acuminate or acute, usually cordate, serrate, glabrescent above, pubescent and covered with red glandular dots beneath, venation pinnate with five or six pairs of lateral veins, the largest pair basal, subsidiary veins prominently reticulate on lower surface.

The seedling ordinarily attains a height of 4 to 8 in. during the first season, while under favourable conditions the growth is more rapid the second year. It is frost-hardy, but is sensitive to drought, dying back in dry places from October onwards; some plants shoot up again from the base, while others are killed outright. At Dehra Dun young plants 1 to 2 ft. high suffered from the attacks of rats, which gnawed through the taproot. The seedling benefits by a certain amount of shade during early youth, and also requires a comparatively moist soil. All those experimental plots at Dehra Dun which were situated in sunny localities were complete failures, the seed usually failing to germinate; the only successful plots were those in which the early stages were spent in partial shade. In northern India the season's growth ceases about November, new growth commencing in February and March.

The following measurements in experimental plots at Dehra Dun give some indication of the rate of growth of seedlings:

Mallotus philippinensis: development of seedlings, Dehra Dun.

Condition under which grown.	Height at end of season.	
	1st season.	2nd season.
	ft. in.	ft. in.
(1) Line sowings along bottom of trench, not watered .	Maximum 0 5	
(2) Sown in box, under shade, well watered .	.. 0 5	
(3) Line sowings with field crops, weeded, not irrigated	.. 0 9	Maximum 3 0
(4) Line sowings with field crops, weeded, not irrigated	.. 1 0	.. 5 0

SILVICULTURAL CHARACTERS. The tree stands a considerable amount of shade. It coppices very well and produces root-suckers. It proved frost-hardy in the severe frost of 1905 in northern India, while in the abnormal drought of 1907 and 1908 in Oudh it was found to be decidedly drought-

resistant, in contrast to what has been found to be the case in the seedling stage. It is not readily browsed by goats and cattle.

NATURAL REPRODUCTION. The seed falls to the ground in the hot season, and germination under natural conditions takes place in the following rainy season. It is of great advantage, and in dry localities essential, that the seed should become covered as soon as possible, partly as a protection against insects, which readily attack the seeds, and partly because seedlings germinating on the surface of the ground are very liable to perish from drought before the root establishes itself. Loose, bare soil is thus of great advantage, as the seed becomes quickly covered during showers of rain. Experiments at Dehra Dun showed that germination under natural conditions is seldom successful except in comparatively moist soil in shady situations; in the open it frequently fails, while any seedlings which do appear tend to die of drought. The establishment of natural reproduction is greatly facilitated by the comparative immunity of this species from damage by browsing, and its prevalence in many localities may be attributed largely to this circumstance.

ARTIFICIAL REPRODUCTION. For the artificial propagation of this tree shade and moisture are necessary in the earlier stages. Fresh seed should be sown about April and lightly covered with earth. Nursery beds should be kept shaded and watered and weeded regularly. Germination begins in about three weeks, and continues for some time; the more vigorous seedlings are ready for transplanting during the first rainy season, but the smaller plants may be kept for a year in the nursery. Line sowings with the aid of field crops have proved successful at Dehra Dun, the field crop affording the necessary side shade during the early months. The crop employed was the lesser millet or *mandwa* (*Eleusine coracana*), which was sown in May and reaped in October. The lines of *Mallotus* were left clear of field crops to a width of about $1\frac{1}{2}$ ft. in order to afford sufficient light to the seedlings, and the results were satisfactory. Owing to the uncertain germinative power of the seed it is advisable to sow the seeds fairly close together, say about 2 in. apart, and to thin out congested seedlings during the first rainy season, employing the surplus plants to fill gaps in the line. Regular weeding and loosening of the soil should be carried out during the first two years, and as often as may be necessary afterwards.

RATE OF GROWTH. The growth is comparatively slow. Periodic measurements of sixteen trees from 1 to 3 ft. in girth in the forests on the south of the Saharanpur Siwaliks in the United Provinces, showed a mean annual girth increment of only 0.26 in. These trees, however, were in sal sample plots, and were probably to some extent suppressed.

Coppice measurements in 1910 by Mr. C. M. McCrie in the Gorakhpur forests of the United Provinces gave the following results:

Mallotus philippinensis: rate of growth of coppice, Gorakhpur.

Age. years.	Mean height. ft.	Mean girth. in.	Age. years.	Mean height. ft.	Mean girth. in.
2	4.8	1.2	10	12.7	4.5
4	7.5	2.2	12	13.7	5.1
6	9.5	3.0	14	14.5	5.6
8	11.3	3.8	16	15.2	5.9

10. TREWIA, Linn.

Trewia nudiflora, Linn. Vern. *Tumri*, *khamara*, *bhillaur*, *gumhar* (which is also the name for *Gmelina arborea*), Hind. ; *Pitali*, Beng. ; *Kat kumbha*, Kan. ; *Pitari*, Mar. ; *Yehmyôk*, *setkadôn*, Burm.

A moderate-sized to large deciduous tree, often with a short bole and spreading branches, but under favourable conditions producing a long clear bole, often much buttressed at the base. Leaves opposite, long-petioled, broadly ovate cordate, giving the tree a superficial resemblance to *Gmelina arborea*. Bark smooth, grey. Wood white, soft, not durable, used for drums, cheap planking, and carved images, and has been reported suitable for match manufacture.

DISTRIBUTION AND HABITAT. Sub-Himalayan tract from immediately west of the Jumna eastwards, Bengal, Assam, Chittagong, Burma, Chota Nagpur, and the Indian Peninsula, chiefly in moist forests and particularly along streams and in moist and swampy situations. This is one of the most characteristic trees of the swamp forests of the western sub-Himalayan tract, where it is often more or less gregarious in association with *Albizia procera*, *Ficus glomerata*, *Diospyros Embryopteris*, *Cedrela Toona*, *Pterospermum acrifolium*, and other characteristic species, together with the cane *Calamus tenuis*. It is common in moist places along the foot-hills of the eastern sub-Himalayan tract, where the trees produce large clear boles often much buttressed at the base. It is sometimes planted on ordinary ground away from streams and swamps, and provided the climate is a fairly moist one it grows tolerably well on fertile soil.

LEAF-SHEDDING, FLOWERING, AND FRUITING. In northern India the leaves turn yellow about November and begin to fall, and the trees are leafless from about December to February or March, when the new leaves appear. The flowers, which are dioecious, appear from January to March, when the trees are leafless or the new leaves are sprouting. The male flowers are in long drooping racemes 3 to 8 in. long, and the females are solitary or two to three together on stout peduncles. In northern India the fruits ripen in July ; for Chota Nagpur, Haines gives May. The fruit (Fig. 310, *a*, *b*) is a globose obscurely quadrangular pale green berry, 1-1.5 in. in diameter, with a fleshy mesocarp of the consistency of a potato, containing usually four seeds, sometimes two, three, or five, each in a separate locule. The seeds (Fig. 310, *c*) are compressed ellipsoidal to globose, about 0.4 by 0.3 in., with a thick hard smooth black testa, and surrounded by a yellowish fleshy arillus ; there is a whitish leathery albumen within the seed. About 150 to 230 seeds weigh 1 oz. Fresh seed gives a fairly high percentage of germination, the best obtained at Dehra Dun being 87 per cent. Seed stored in tins was found not to retain its vitality for one year ; nevertheless in one case seed sown in the ground under shade remained fertile and germinated a year later. The extraction of the seeds from the fruit is best effected by spreading the ripe fruits in the sun for a few days, when they become soft and the seeds can be pressed out.

The fruits are buoyant in water, a matter of importance in connexion with the dissemination of the seed in the riverain tracts where the tree

commonly grows ; the fact that the fruits ripen in the rainy season when the streams are swollen is a further advantage in spreading the seed.

GERMINATION (Fig. 310, *d-f*). Epigeous. The testa splits in two, the radicle emerging and a ring of lateral rootlets being produced almost at once round the base of the young taproot. The hypocotyl elongates by pronounced arching, and in straightening raises above ground the cotyledons, which then expand, becoming green and foliaceous. The testa is usually left in or on the ground, while the leathery albumen, enclosing the cotyledons like a bag, is carried up, splitting and falling off with their expansion.

THE SEEDLING (Fig. 310).

Roots : primary root long, at first thin, rapidly thickening, terete, tapering, white, turning yellowish brown ; lateral roots numerous, fibrous, at first round base of taproot, later distributed down it, rootlets round base longer than those farther down. **Hypocotyl** distinct from the root, 1.5–2 in. long, terete, tapering upwards, delicate, green, glabrous or very finely pubescent in upper part. **Cotyledons** : petiole 0.2–0.3 in. long, channelled above ; lamina 1–1.3 in. by 0.9–1.1 in., thin, foliaceous, broadly elliptical or elliptical ovate, obtuse, base obtuse or sub-truncate, entire, green, glabrous, prominently 5-veined from the base. **Stem** erect, terete, green or pinkish, pubescent, 0.5–1.3 in. long. **Leaves** simple, alternate, or first one or two pairs opposite or sub-opposite ; stipules absent. Petiole 0.6–1 in. long, channelled above, later terete, green or pink, pubescent. Lamina 1.5–2.5 in. by 0.8–1.6 in., cordate, acuminate, dentate or undulate, sometimes entire, pubescent, venation reticulate, with five basal nerves.

The above description refers to seedlings of the first season. A remarkable character in the case of *Trewia* seedlings and coppice-shoots is the fact that on the main stem the leaves and branches are alternate, while on the side branches they are opposite. Seedlings of *Gmelina arborea*, to which those of *Trewia* bear a superficial resemblance, have all leaves opposite.

The growth of the seedling during the first year is comparatively slow, a height of 5 to 10 in. being ordinarily attained by the end of the season. Sometimes natural seedlings do not produce more than the cotyledons during the first season, the foliage leaves beginning to appear only the following year. Under favourable conditions growth after the first year is rapid, vigorous plants growing 5 ft. or more in a season. Weeding and irrigation, particularly the former, greatly stimulate growth, while the development of the young plant suffers in the presence of weeds. The taproot, which shows moderate development during the first season, subsequently lengthens and thickens considerably, a length of 4 ft. or more being sometimes attained by the end of the second season, while at the same time large lateral roots develop round the base of the taproot immediately below ground-level.

The seedlings are fairly frost-hardy but are sensitive to drought, from which they may be killed outright or partially killed, with the result that forked stems are produced. Side shade from the sun has proved an efficient protection from drought in the case of line sowings. Young plants endure slight shade, but become suppressed under heavy shade. In the struggle for existence the more vigorous plants readily suppress the weakly ones.

The growth of seedlings is suspended for a comparatively short time in winter ; it hardly stops at all if the plants are regularly watered, but other

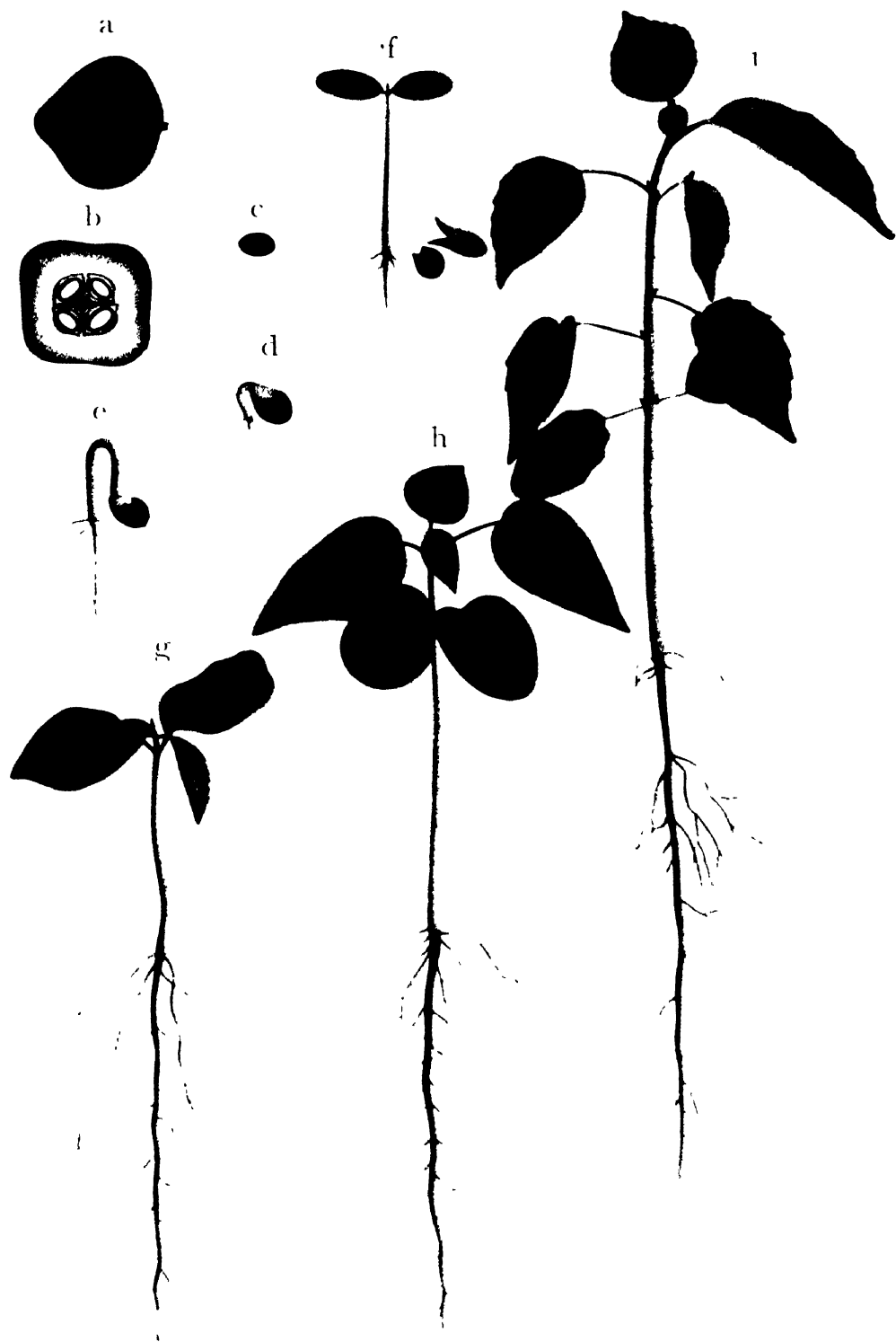


FIG. 310 *Irewia nudiflora* SEEDLING $\times \frac{1}{2}$

a - Fruit b - Fruit in section c - Seed d - f - Germination stages
g - i - Development of seedling during first season

wise ceases about December, new growth starting in February or March. The leaves commence falling in December, and have usually all dropped by the end of February. These dates apply to northern India.

The following measurements in experimental plots at Dehra Dun give some indication of the rate of growth of young plants under different conditions, and exhibit the marked effect of weeding :

Trewia nudiflora : development of seedlings, Dehra Dun.

Condition under which grown.	Height at end of season.			
	1st season.	2nd season.	3rd season.	4th season.
1) Plants in nursery, weeded and watered	0 ft. 3 in.-0 ft. 9 in.	Maximum 5 ft. 0 in.		
2) Plants in nursery, weeded and watered	0 ft. 3 in.-0 ft. 10 in.	.. 7 ft. 0 in.		
3) Plants in nursery, weeded and watered	Maximum 0 ft. 6 in.	.. 6 ft. 3 in.	3 ft. 3 in.-13 ft. 2 in.	Maximum 15 ft. 0 in.
4) Transplants of 1st season, not weeded or watered after transplanting	.. 0 ft. 6 in.	.. 1 ft. 5 in. (thick growth of grass and weeds)	0 ft. 10 in.-1 ft. 5 in. (growth hindered by weeds)	
5) Transplants of 1st season, not weeded or watered after transplanting	.. 0 ft. 5 in.	Maximum 2 ft. 7 in.	No further growth owing to suppression by weeds	
6) Fruits scattered on ground, as under natural conditions; subsequently weeded, not watered	.. 0 ft. 5 in.	.. 5 ft. 1 in.	1 ft. 2 in.-10 ft. 2 in.	Maximum 16 ft. 8 in. (girth 0 ft. 7 in.).
7) Line sowings, irrigated, weeded	.. 0 ft. 8 in.	1 ft.-5 ft. 3 in.	Maximum 10 ft. 0 in. (vigorous)	
8) Linesowings, irrigated, unweeded, adjacent to (7)	.. 0 ft. 11 in.	0 ft. 8 in.-5 ft. 6 in. (only 2 large plants where weeds absent).	Little further growth: condition poor owing to weeds	
9) Line sowings, unirrigated, weeded	.. 0 ft. 8 in.	0 ft. 3 in.-3 ft. 10 in.	0 ft. 3 in.-5 ft. 7 in. (partially killed back by drought during the year)	
10) Line sowings with field crops; unirrigated, weeded	.. 0 ft. 5 in.	Maximum 3 ft. 2 in.	0 ft. 4 in.-2 ft. 9 in. (line fairly well stocked)	} Killed back by drought in 3rd season.
11) Line sowings with field crops; unirrigated, unweeded, adjacent to (10)	.. 0 ft. 5 in.	.. 2 ft. 11 in.	1 ft. 2 in.-2 ft. 8 in. (only 5 survivors)	

SILVICULTURAL CHARACTERS. The tree is a moderate light-demander. It coppices vigorously and produces root-suckers, sometimes in great quantity, from its superficial roots, which spread in a network near the surface of the ground. It is fairly frost-hardy, but is sensitive to drought; it suffered considerably in Oudh in the abnormal drought of 1907 and 1908, when the streams along which it grew dried up.

NATURAL REPRODUCTION. The ripe fruit falls early in the rainy season, much of it falling around the trees and germination taking place *in situ*, while some of it is transported to a distance by water. The fruit after reaching the ground soon rots; the fleshy mesocarp becomes soft and is further disintegrated by heavy rain, partially exposing the seeds, which germinate at different times throughout the rainy season. The seedlings often appear in little groups of three or four together, each group representing the collection of seeds in a single fruit. Experiments at Dehra Dun showed that dry or hard ground is unfavourable for germination, while seedlings readily spring up on

moist loose soil. Germination is more successful if the fruits and seeds become wholly or partially buried than if they lie on the surface of the ground ; in this respect the loose alluvial soil on which the fruits often fall or are stranded by water is particularly favourable.

ARTIFICIAL REPRODUCTION. The fruits should be collected as soon as they ripen, early in the rainy season, the seeds being extracted in the manner already described and sown at once. It is of importance to sow early, in order that the seedlings may develop as far as possible during the first year, since they are handicapped naturally by a late start. Direct sowing in lines has proved more satisfactory at Dehra Dun than transplanting from the nursery, although the latter proved quite successful where plants a few weeks old were put out before the end of the rainy season. The soil of the seed-beds should be porous. The seeds may be sown 3 in. apart in drills 9 in. apart, and should be covered with earth to a depth of about $\frac{1}{4}$ in. ; the beds should be weeded regularly and watered copiously in dry weather. Germination usually begins in ten to fourteen days.

Line sowings have proved very successful at Dehra Dun, particularly where irrigation was carried out, the seeds being sown along the base of the ridge of earth heaped up alongside the water-channel, on the side next the channel. Unirrigated line sowings in conjunction with the raising of field crops on ploughed land also proved thoroughly successful. The crop employed was the lesser millet or *mandwa* (*Eleusine coracana*), which was sown towards the end of May and reaped in October. It was found slightly advantageous to leave a clear line about $1\frac{1}{2}$ to 2 ft. wide unsown with crops, along which the *Trewia* seeds were sown ; but even where the crops were sown continuously the results were fairly good, though the development of the seedlings during the first season was somewhat poorer than along the cleared lines where they were free from suppression by the crops.

In line sowings 1 lb. of seed suffices for about 550 ft. of line. It is essential that regular weeding and loosening of the soil should be carried out, and in the second year the young plants should be thinned out where they are congested ; in the first rainy season surplus seedlings should be removed and transplanted to fill gaps, and this is a further reason for leaving clear lines in sowing with field crops.

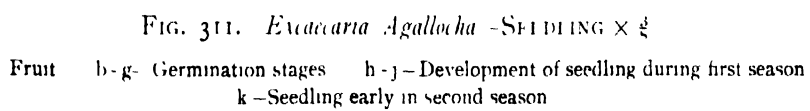
Propagation by cuttings was tried at Dehra Dun. Cuttings planted in the rainy season sprouted well, but invariably died off in the ensuing dry weather. They might possibly succeed in ground which is permanently moist.

11. EXCAECARIA, Linn.

Seven Indian species of trees or shrubs with acrid juice, of somewhat local distribution except *E. Agallocha*, Linn., which is a common littoral species.

Excaecaria Agallocha, Linn. Blinding tree. Vern. *Gengwa*, *geor*, *geria*, Beng. ; *Geva*, *suran*, *surund*, Mar. ; *Tilai*, Tam. ; *Thilla*, Tel. ; *Tayaw*, *kayaw*, Burm.

A small evergreen bushy tree, sometimes attaining 30 ft. in height, but often stunted and crooked, with stout smooth branches and shining elliptical ovate leaves. Bark grey, smooth, covered with prominent lenticels. Wood



soft, whitish, used chiefly for fuel, but suitable for purposes for which a soft white wood is required. The tree exudes a very acrid poisonous juice, particularly from the fresh cortex when cut, which raises blisters on the skin and is injurious to the eyes of wood-cutters, whence the name 'blinding tree'.

DISTRIBUTION AND HABITAT. Common in tidal forests on both sides of the Indian Peninsula, the Sundarbans, Chittagong, Burma, and the Andamans. In the Sundarbans it is fairly well distributed throughout the tidal forests, mixed with *Heritiera Fomes* and *Ceriops Candolleana*. As a general rule *Ceriops* springs up first on the newly formed islands, *Excaecaria* appearing next as the ground becomes more elevated, while *Heritiera* comes in last on the highest and driest ground.

FLOWERING AND FRUITING. The minute yellowish green flowers appear about July, and the fruits ripen in August and September. The fruit (Fig. 311, *a*) is a 3-lobed capsule 0.3–0.5 in. or more in diameter. The seed is 0.2 in. in diameter, globose, with a moderately hard but brittle testa and with albumen surrounding the embryo; about 250 seeds weigh 1 oz. on an average. Under natural conditions the seed germinates immediately after falling. Tests at Dehra Dun showed that the germinative power is high.

GERMINATION (Fig. 311, *b-g*). Epigeous. The testa cracks and the radicle emerges at one end of the seed. The hypocotyl elongates, with slight arching, carrying above ground the cotyledons enclosed in the albumen and testa, which eventually fall to the ground when the cotyledons expand.

THE SEEDLING (Fig. 311).

Roots: primary root moderately long and thick, terete, tapering; lateral roots moderate in number and length, fibrous. **Hypocotyl** distinct from root, 2.8–4.2 in. long, quadrangular in the upper part, more or less terete below, tapering slightly upwards, red or green, glabrous. **Cotyledons:** petiole 0.1–0.2 in. long, flattened above; lamina 0.6–0.9 in. by 0.5–0.8 in., foliaceous, somewhat fleshy, orbicular, entire, green, glabrous, with three conspicuous and two less conspicuous veins from the base. **Stem** erect, terete or slightly compressed, green turning brown, glabrous; internodes 0.3–1.2 in. long. **Leaves** simple, alternate. Stipules minute. Petiole 0.4–0.7 in. long, channelled above, sometimes red, glabrous. Lamina 1.2–2.5 in. by 0.6–1.3 in., ovate lanceolate, acuminate, remotely serrate crenate, dark green, glabrous, shining, midrib sometimes red.

Seedlings raised at Dehra Dun in moist earth attained a height of 4 to 5 in. during the first season, 1 to 1½ ft. by the end of the second season, and 4 to 4½ ft. by the end of the third season.

ARTIFICIAL REPRODUCTION. Seedlings have been raised in large numbers at Dehra Dun by sowing fresh seed in boxes of moist earth and transplanting in the rainy season when the plants were a year old; transplanting proved quite successful. In the natural home of the tree broadcast sowings *in situ* are likely to give good results, as the seed germinates readily and has a high percentage of fertility.

RATE OF GROWTH. In the Sundarbans the growth is said to be slow, particularly in salt-water areas.

12. SAPIUM, P.Br.

Five species of soft-wooded trees, one introduced.

Species 1. *S. sebiferum*, Roxb.; 2. *S. insigne*, Benth.

1. *Sapium sebiferum*, Roxb. Syn. *Excaecaria sebifera*, Muell. Arg. Chinese tallow tree. Vern. *Vilayati shisham*, Hind.

A moderate-sized deciduous tree, often with a gnarled trunk, with leaves somewhat resembling the leaflets of *Dalbergia Sissoo*. Bark grey, with vertical cracks. The seeds are coated with a white wax, separable by boiling in water, used in China and Japan for making candles. Puran Singh found that in India its value as a tallow- and oil-yielding plant has been somewhat underrated in the past; according to him the tallow and oil should be extracted by the aid of a solvent extraction plant and not by bruising the seeds and steaming them as in China, since the yield of tallow by the latter process is at least 50 per cent. less than by the former.

The tree is a native of China, but is largely cultivated in northern India, occasionally up to 6,000 ft. in the Himalaya; also sometimes in other localities, including Burma. In the Changa Manga plantation near Lahore it does well only near water. In northern India it has run wild and has spread extensively, not only from seed but also by means of root-suckers, which it produces in great abundance, and as it is not browsed by cattle it is able to survive in grazed areas. It coppices well. The tree is frost-hardy, and stands a certain amount of shade. In order to run wild it seems to require a fairly heavy rainfall or else a moist soil. It has established itself thoroughly around Dehra Dun, particularly on gravelly soil in ravine lands, in the moister parts of the Kangra valley and on islands in the Jhelum river on the plains. It is a useful tree for fixing sides of ravines and banks of rivers. It is easily raised from seed, and can also be grown from cuttings. The leaves turn a beautiful orange to scarlet colour in the autumn, and fall early in the cold season, the trees remaining leafless till about April. The greenish yellow monoecious flowers, in terminal racemes, appear from June to August; they are very fragrant and are visited by swarms of bees. The fruits ripen from November to January; the fruit is a sub-globose 3-valved capsule, with three seeds coated with a white wax. The rate of growth is fast. Parker says that in the Jhelum Chhanda plantation it averages three rings per inch of radius, giving a mean annual girth increment of 2.09 in. Gamble gives six rings per inch of radius, or a mean annual girth increment of 1.05 in.

2. *Sapium insigne*, Benth. Syn. *Excaecaria insignis*, Muell. Arg. Vern. *Boddar*, *khinna*, W. Him.; *Ure*, *dudla*, Mar.; *Kurda*, Kan.

A deciduous tree, usually of small or moderate size, but sometimes attaining fairly large dimensions, with large elliptic or oblong-lanceolate leaves crowded at the ends of the branchlets. Bark smooth in young trees, corky and very rough with deep furrows when old, exuding when cut a thick milky acrid juice, which is said to be poisonous. The wood is soft, white, and spongy. The tree is common, though scattered, along the Himalayan foot-hills, ascending to 5,000 ft. or more, usually in dry rocky situations; also in western India from the Konkan southwards, the hills of Kurnool and Cuddapah, Assam, Chittagong, and the Pegu Yoma in Burma. Talbot says that it is common on

laterite near the coast of North Kanara and the Konkan, and sometimes in monsoon forest on the *ghats*, but always in dry rocky localities, and that on account of its poisonous qualities it and *Strychnos Nux-vomica* are the only trees found over large areas in the evergreen scrub along the North Kanara coast.

The tree is leafless from December to April, when it is easily recognized from the long terminal erect flowering and fruiting spikes, the flowers appearing in the cold season and the fruits ripening in the following hot season. It can be easily grown from cuttings taken from the ends of the shoots.

13. MACARANGA, Thouars.

Fast-growing, soft-wooded, and short-lived trees or shrubs, usually with large peltate leaves. Ten Indian species, some of them important by reason of their capacity for rapidly reclothing forest clearings and savannahs.

Species 1. *M. pustulata*, King ; 2. *M. indica*, Wight ; 3. *M. Roxburghii*, Wight ; 4. *M. Tanarius*, Muell. Arg. ; 5. *M. denticulata*, Muell. Arg.

1. *Macaranga pustulata*, King. Vern. *Mallata*, Nep.

A small often gregarious tree of the Himalaya from Kumaun eastwards at 3,000 to 6,000 ft., chiefly on old clearings. The leaves are not peltate. The tree is comparatively short-lived, and soon gives place to other species, but the growth is very rapid ; Gamble says that in ten years it may reach a height of 40 ft. with a girth of 3 ft.

2. *Macaranga indica*, Wight. Vern. *Papri*, Dehra Dun ; *Rámálo*, Kumaun ; *Jogi mallata*, Nep. ; *Vatta thamarei*, Tam.

A small evergreen often gregarious tree with peltate leaves and smooth grey bark. Outer Himalaya locally from the Malkot hills, Dehra Dun, eastwards at 3,000 to 5,000 ft., Assam, Andamans, the hills of southern India, and in moist ravines in Singhbhum, Chota Nagpur ; also in Ceylon. The growth is rapid ; Gamble gives 3 rings per inch of radius (one specimen), representing a mean annual girth increment of 2.09 in.

3. *Macaranga Roxburghii*, Wight. Syn. *M. tomentosa*, Wight. Vern. *Chanda*, Mar. ; *Upaligi*, Kan. ; *Vatta*, Tam.

A small or moderate-sized resinous tree with peltate leaves and dark grey, fairly smooth bark, common in the evergreen forests of the Western Ghats : also in the hills of the Deccan and Circars and the hills of southern India. It comes up plentifully on old clearings, and is of rapid growth.

4. *Macaranga Tanarius*, Muell. Arg. Syn. *M. moluccana*, Wight.

A species which springs up freely on newly cleared areas in the Andamans.

5. *Macaranga denticulata*, Muell. Arg. Vern. *Mallata*, Beng. Duars ; *Taung petun*, Burm.

A soft-wooded moderate-sized evergreen tree with a smooth light grey stem and peltate broadly ovate acuminate leaves, somewhat glaucous beneath. It reaches a height of 60 ft. or even more, and a girth of 4 ft. or more, tending to branch low down and to send up several straight limbs like the spokes of an umbrella, though if forced up between other trees it forms a straight single stem. The crown is light, consisting of a single layer of leaves, and the canopy forms a thin umbrella-like cover. The root-system is superficial, young saplings being easily pulled up by hand.

The natural habitat of the tree is in the sub-Himalayan tract from Sikkim eastwards, ascending occasionally to 5,000 ft., Assam, Chittagong, and Burma. It thrives in a moist warm climate, and will not tolerate frost or drought. In the Bengal Duars it flowers in March–April, and the fruit ripens about July; the seed is small and spreads to a remarkable degree, and in localities where the soil and climate favour it the tree quickly invades open ground, springing up luxuriantly on abandoned forest clearings and on fire-protected savannah lands. Mr. Rodger informs me that he has observed it to be an excellent tree for reclothing abandoned hill *taungya* (shifting cultivation) in the Katha district of Upper Burma at 2,000–3,000 ft. The growth is very rapid; trees of known age in the Muraghat forest, Jalpaiguri, were found to have an average height of 30 to 35 ft. in eight years, and 50 ft. in thirteen years, while the average and maximum girths at eight years were 1 ft. and 2 ft. 2 in. respectively. The tree coppices, at all events in its younger stages. Young plants are very liable to be browsed by deer.

In the Duars tract *Macaranga* has no equal as a natural afforesting agent in fire-protected savannahs, quickly killing out the grass and in turn making way for shade-bearing and usually evergreen species. It is very sensitive to fire, but as soon as fire-protection is introduced it is probably the most invasive tree in the tract in question; burning kills it out equally rapidly. When fire-protection is introduced it regenerates profusely not only on bare ground, but also on grass-lands, in gaps in the forest and even under slight shade; it is not found in the driest parts of the Duars, but is abundant throughout the moister parts, and occurs even on fairly swampy ground.

The progressive succession from burnt savannah or semi-evergreen forest in the Duars, in which *Macaranga* plays a prominent part, is an interesting study. The successive stages are illustrated in Figs. 312 to 315, which show the establishment of *Macaranga* on the introduction of fire-protection in the savannahs of this tract; where conditions are favourable its rapid growth soon pushes it through the tall grasses, which do not long survive the unequal struggle and are killed out. A stage then usually follows when the ground under the canopy of the *Macaranga* is bare or nearly so, or seedlings of sal or other species may be found on the ground, though such seedlings are unable to establish themselves unless they are of decidedly shade-bearing and moisture-loving species. Where the locality is moist a soil-covering of ferns often appears. Simultaneously or subsequently shade-bearing, and for the most part evergreen species of trees, shrubs, and climbers make their appearance; the trees grow up through the *Macaranga* and kill it out, and the shrubs form a dense undergrowth, the climbers, together with canes, helping to form an impenetrable mass. This transition can be seen in all stages, and is often rapid.

The capacity of the *Macaranga* for killing out savannah grasses has from time to time been regarded as a useful means of obtaining natural reproduction of sal, but, as has been explained in Vol. I, p. 100, under *Shorea robusta*, my own observations in the Duars have led to an exactly contrary conclusion. for although sal seedlings may often be found in quantity under *Macaranga*, no case has yet been observed in which they have been able to establish themselves under its canopy. This does not, however, detract from the importance



FIG. 312. Progressive succession from savannah to evergreen forest through the medium of *Macaranga denticulata*. Bengal Duars: (1) *Macaranga* overtopping savannah grasses and killing them out.



FIG. 313. Progressive succession from savannah to evergreen forest through the medium of *Macaranga denticulata*, Bengal Duars (2) dense crop of *Macaranga*, which has killed out the savannah grasses.

of *Macaranga* as an agent in effecting the introduction of shade-bearing species in savannah lands, while it may yet prove to be similarly useful in the introduction of sal and other more or less light-demanding species provided it is cut out as soon as it has performed its useful function of killing out a rank growth of grass.

The tree can be easily raised by sowings, the seed being scattered in the rainy season, when it ripens. Fig. 316 shows the result of sowing up a former savannah tract.

14. CROTON, Linn.

A fairly large genus of trees, shrubs, and climbers, mostly of little or no importance in Indian forestry. Perhaps the commonest is the following :

Croton oblongifolius, Roxb. Vern. *Arjunna*, Oudh ; *Akh*, Nep. ; *Gunsur*, Mar. ; *Thityingyi*, Burm.

A moderate-sized deciduous tree of the sub-Himalayan tract from Oudh eastwards, Chota Nagpur, rare in Bombay ; Burma, in upper mixed forests. This tree is very common in the forests of Gonda in Oudh, often occurring gregariously in belts on undulating or flat ground along the base of the outer hills. It is often planted for ornament. Its leaves assume a bright red colour before falling. It reproduces freely by root-suckers, and coppices well. Measurements made in 1910 by Mr. C. M. McCrie in coppice coupes in Gorakhpur, United Provinces, gave the following rate of growth as compared with that of sal :

Croton oblongifolius : rate of growth of coppice, Gorakhpur.

Age. years.	Mean height.		Mean girth.	
	<i>Croton</i> . ft.	Sal. ft.	<i>Croton</i> . in.	Sal. in.
2	3.8	3.0	..	..
4	7.0	7.0	1.6	2.0
6	9.5	10.3	2.3	2.9
8	11.6	13.0	3.0	3.8
10	13.2	15.3	3.7	4.8
12	14.7	17.5	4.2	5.8
14	16.2	19.2	4.6	6.7
16	17.5	20.9	5.0	7.5

15. JATROPHA, Linn.

Shrubs or perennial herbs. There are four indigenous and three introduced species, two of the latter, *J. gossypifolia*, Linn., and *J. Curcas*, Linn., natives of South America, being of more importance than the indigenous species. *J. Curcas* is much cultivated as a hedge-plant in village lands, and is not browsed ; it grows readily from cuttings. The seeds yield an oil used for burning and in medicine. *J. gossypifolia* has run wild in many parts of India. It is carefully avoided by cattle, and forms thick clumps on heavily grazed areas, acting as a protection to tree species, which establish themselves under its protection. Even grass growing amongst it, which can be reached by cattle, is not readily eaten, showing that for some reason the mere presence of the shrub is obnoxious.

16. HEVEA, Aubl.

Hevea brasiliensis, Muell. Arg. Pará rubber.

A large evergreen tree with glabrous trifoliate leaves on long petioles. This tree is the most important source of caoutchouc in the world, and furnishes the well-known Pará rubber of commerce.

HABITAT. The natural home of the tree is the Amazon valley in Brazil, where it grows in dense moist forest on deep rich soil at low elevations, extending down to low-lying, often inundated lands, and even to the edge of tidal limits. The climate is characterized by high atmospheric humidity and great uniformity of temperature, the absolute maximum and minimum temperatures being about 95° and 74° F. respectively, and the mean temperature at sea-level averaging from 77° to 81° F. The rainfall is 80 in. or over; the rain falls chiefly between January and June, little falling during the remaining six months, though periods of drought are seldom of more than two months' duration.

As the tree has been so much planted outside its natural habitat it will be useful to consider the conditions under which it has been found to thrive. Generally speaking the temperature should be warm and equable, with a range of about 75° to 95° F. A rainfall of 70 to 150 in. is probably the most favourable, but a well-distributed rainfall is of much greater importance than a copious one. Heavy and prolonged deluges of rain with a dark cloudy sky for many days in succession are unfavourable, as are long intervening periods of drought; the ideal is an alternation of moderate showers at fairly frequent intervals with warm bright weather. The atmosphere should be moist but not saturated. The most favourable situation is a valley well sheltered from strong and dry winds by hills or by belts of high forest, preferably evergreen, at a low elevation, that is, up to about 2,000 or 2,500 ft. The ground should not be swampy or water-logged. Deep, rich, well-drained river alluvium is excellent, but undulating ground, provided the soil is deep, rich, and well drained, is equally good; steep, broken, or rocky hill-sides are not suitable. The soil should be a deep, rich, moist, porous loam, containing a fair percentage of clay; the soil which produces moist evergreen forest is as a rule suitable. The subsoil should be well drained, preferably sand and gravel. A stiff clayey subsoil is unfavourable, but laterite, if soft and if overlain by a reasonable depth of soil, is not unsuitable.

INTRODUCTION INTO THE EAST. The early introduction of *Hevea brasiliensis* into the East was undertaken by Kew at the expense of the Indian Government. In 1873 seeds, obtained from the Amazon by Mr. J. Collins, were forwarded by Mr. (afterwards Sir Clements) Markham to Kew, but owing to the rapid deterioration of the seed in transit, only about a dozen plants were raised. Six of these were brought out to Calcutta by Dr. King, and from these others were raised by cuttings. The plants were tried both at Calcutta and in Sikkim, but these localities proved unsuitable. In 1876 Mr. H. A. Wickham brought from Pará to Kew 70,000 seeds, of which about 2,500 are said to have germinated. From this supply 1,919 plants were in the same year sent to Ceylon, and about 1,700 arrived in good condition. Smaller supplies were at the same time sent to Burma, Singapore, Java, and elsewhere. Those

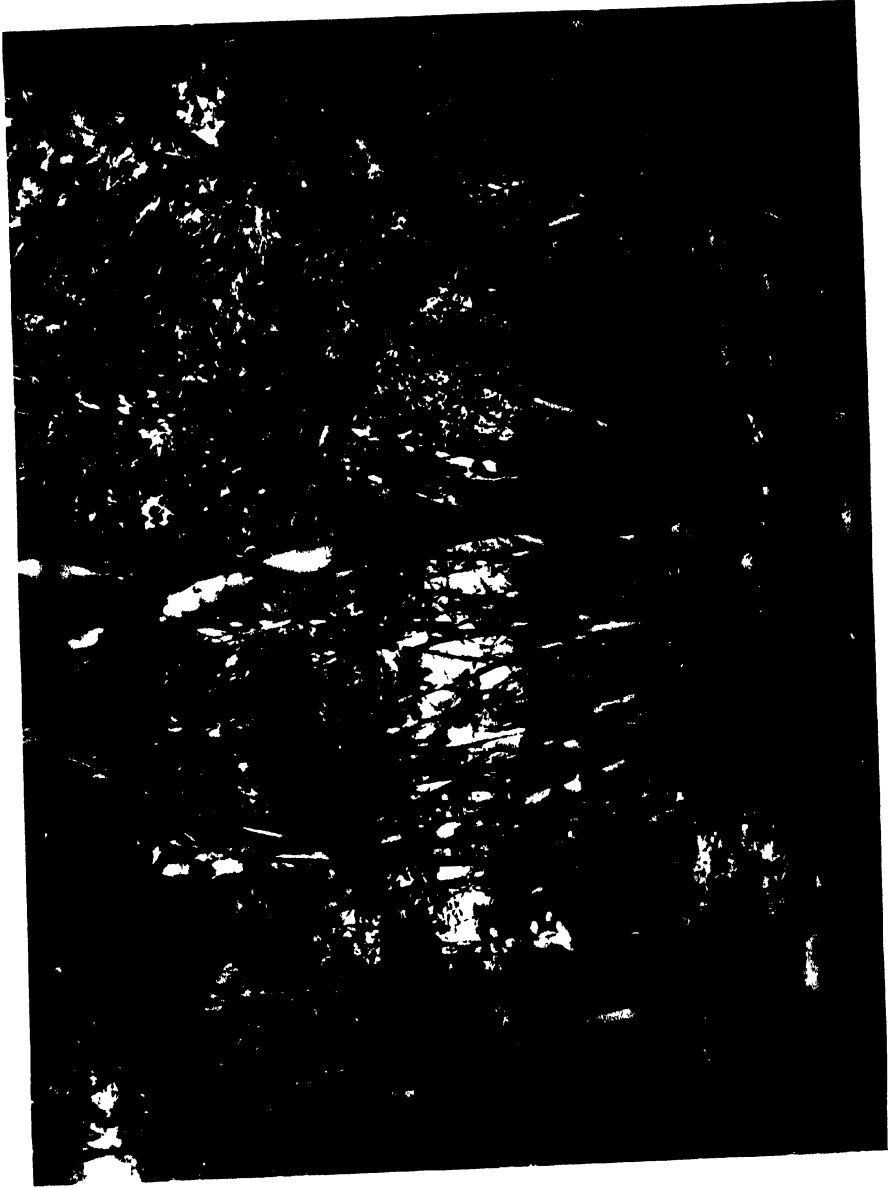


FIG. 314 Progressive succession from savannah to evergreen forest through the medium of *Macaranga denticulata*, Bengal Duars (3) interior of *Macaranga* crop after savannah grasses have been killed out, no undergrowth yet appeared

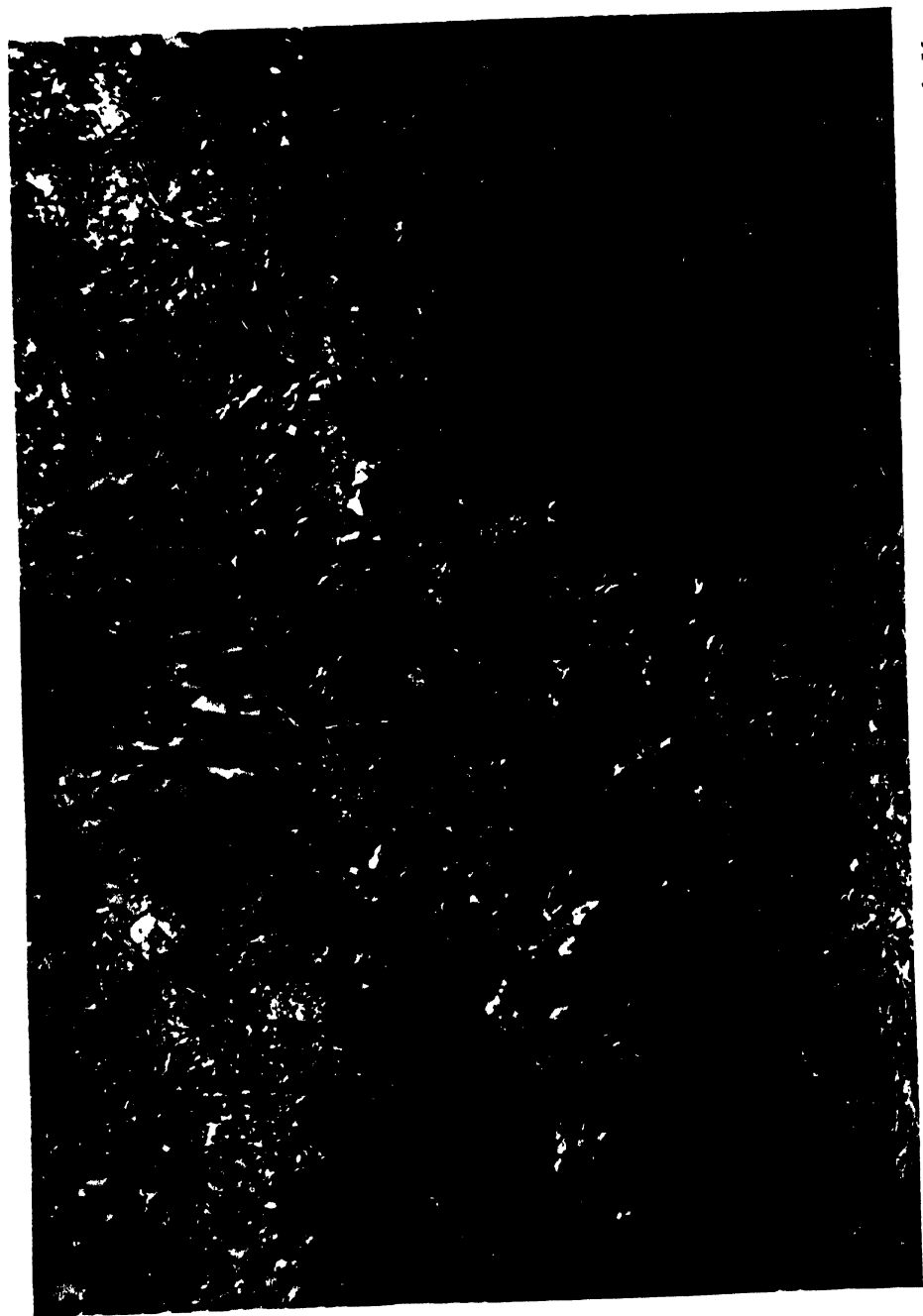


FIG 315. Progressive succession from savannah to evergreen forest through the medium of *Macaranga denticulata*. Bengal Duars : (4) shade-bearing evergreen species appearing under cover of *Macaranga* the former will eventually make their way through the latter and kill it out

sent to Burma all died, but later in the year Mr. Duthie took out another case of plants to Calcutta ; some were sent to Assam and sixteen were sent in 1877 to Burma, of which eight survived and were planted in the Forest office compound at Mergui. Meanwhile in 1876 Mr. R. Cross brought to England from Pará over 1,000 seedlings, of which hardly 3 per cent. survived. From these cuttings were propagated and about 100 plants were sent to Ceylon, small parcels being sent to Singapore, Java, and elsewhere. The plants thus distributed in the seventies of last century, mainly to Ceylon, formed a useful nucleus for the production of seed for the extension of rubber planting in the East, which commenced on a small scale in the eighties of last century and has proceeded more recently on an extensive scale in Ceylon, Malaya, Borneo, Sumatra, Java, southern India, and Burma.

In the Indian Empire Pará rubber has so far been grown successfully in three regions, southern India, Burma, and the Andamans. It was first introduced into southern India in 1879, when twenty-eight plants received from the Royal Botanic Gardens, Ceylon, were planted at Nilambur in South Malabar. These were neglected and many were allowed to die, but some still survive. The first rubber estate in southern India was started in 1902 at Thattakad on the banks of the Periyar river in Travancore. Further estates were opened there in 1904, and these were followed in 1905 by the opening of estates in Cochin ; since then many other estates have been started, and in 1917 the total area under rubber (mainly *Hevea*) was 47,631 acres, distributed as follows : Travancore, 30,144 acres ; Malabar, 8,783 acres ; Cochin, 7,425 acres ; Nilgiris, 1,065 acres ; and Salem, 214 acres.

The introduction of Pará rubber into Burma dates, as already mentioned, from 1877, when eight plants were planted at Mergui. In the following year an area of 59 acres was planted by the Forest Department at Mergui. Various experiments in rubber planting have been undertaken since then. Among the earlier efforts may be mentioned a small experimental plantation started in 1899 by the late Mr. W. S. Todd at Kyaukadat, eight miles from Amherst. An experiment on a larger scale was commenced by the Forest Department in 1901 by the formation of a rubber plantation at Mergui. This plantation was continued until 1910, when the area aggregated about 1,660 acres ; by that time the plantation had fulfilled its object, namely to prove that rubber could be grown successfully in Tenasserim, and it was accordingly leased to a company. Rubber is now successfully grown in many parts of Lower Burma. Even as far north as Myitkyina trees have, contrary to expectation, been found to grow well and to yield a fair amount of latex. In 1917 the total area under rubber in Burma was 63,567 acres, the chief rubber-growing districts being Mergui, 22,454 acres ; Amherst, 8,028 acres ; Thaton, 7,969 acres ; Tavoy, 5,153 acres ; Hanthawaddy, 5,087 acres ; Insein, 4,939 acres ; Toungoo, 4,547 acres ; Myitkyina, 4,232 acres : there are small areas in a few other districts.

Pará rubber was first introduced into the Andamans in 1887. Plantations were commenced by the Forest Department in 1905, and were extended subsequently, the total planted area in 1918 being 500 acres. The growth is good, and the plantations are promising.

Plantations of Pará rubber have been tried on an experimental scale in

Bengal and Assam, but the industry has never been taken up in those provinces, and the prospects are apparently not good. In Bombay rubber has been tried in Kanara, but has not proved a success; the rainfall is heavy, but the deluges of rain in July and August with an almost total absence of sunshine, alternating with a long dry season between October and June, are conditions which the plants appear to be unable to contend with.

PROPAGATION AND TREATMENT. The propagation and treatment of this important tree in the East has been the subject of detailed investigation by various workers, particularly in Ceylon and the Malay States, and there is an extensive literature dealing with its propagation and treatment, tapping systems, pests, and diseases, and other matters relating to it.

The practical rubber planter will find much of value in such publications as the following: (1) *Hevea brasiliensis*, by Herbert Wright; (2) *The Cultivation and Preparation of Pará Rubber*, by W. H. Johnson; (3) *Notes on Rubber Cultivation*, by Lieutenant-Colonel J. A. Wyllie and O. G. Ferreira (Madras: Higginbotham & Co.); (4) *Rubber and Rubber Planting*, by R. H. Lock (Cambridge University Press); (5) *Rubber in the East*, being the official account of the Ceylon Rubber Exhibition, 1906, ed. J. C. Willis, M. Kelway Bamber, and E. B. Denham; (6) *Bulletins of the Department of Agriculture*, Ceylon; (7) *Circulars and Agricultural Journal of the Royal Botanic Gardens*, Ceylon; (8) *The Agricultural Bulletin of the Straits and Federated Malay States*; and (9) *The Cultivation of the Pará Rubber Tree in Burma*, by A. M. Sawyer (Department of Agriculture, Burma, Bulletin No. 7, 1911). Frequent articles on rubber appear in the *Tropical Agriculturalist*, Colombo, and occasional papers appear in the *Agricultural Journal of India*. The pages of the *Indian Forester* at one time contained articles on *Hevea*, but this tree now concerns the planter rather than the forest officer, and that journal does not now ordinarily contain information regarding it.

It is therefore unnecessary here to enter into details on the subject, though a few remarks on conditions in Burma and southern India which differ from those obtaining in the Malay States may not be out of place. In Burma and in most parts of southern India in which rubber planting is carried out, planters are faced with a heavy rainy season alternating with a long dry season extending over several months, during which little or no rain falls, while in the Malay States sufficient moisture may be said to be present almost throughout the year. In Burma and southern India, therefore, special precautions are necessary to preserve the soil moisture during the dry season, and this is best effected by means of green mulching and keeping the soil to a depth of several inches in a state of fine tilth. This can be done by mulching weeds into trenches and then harrowing and cross-harrowing until a deep loose fine tilth is obtained. Disk harrows have proved most effective for this work. 'Scrape' weeding, that is, scraping weeds off the surface of the ground, has proved distinctly harmful in Burma and India, since not only does it fail to conserve moisture in the dry season, and cause the exposure of the roots by the gradual removal of the surface soil, but during the monsoon it causes denudation and the formation of ruts and channels where the ground slopes. This is liable to occur with any system of clean weeding, and accordingly on some estates the effective plan has been adopted of introducing leguminous cover crops such as *Erythrina* and *Crotolaria*. The former when high enough is cut half through, bent over, and pegged down, a dense cover being formed which prevents the growth of

weeds. Thereafter the shoots are cut from time to time and laid on the ground as a mulch.

As regards the efficacy of cultivation and mulching, Mr. Fenoulhet notes that in the Shwegyin rubber estate, Burma, in April 1915, a crop of 4,553 lb. was obtained from 184,183 trees. During 1915 systematic cultivation and mulching was carried out by forking and harrowing. In 1916 a crop of 13,129 lb. was obtained from only 99,999 trees, every alternate row being rested throughout the dry months, that is, an increase of 8,576 lb. was obtained from 84,184 trees less, under exactly similar climatic conditions, which is well above the normal increase for an estate averaging eight years in age.

A point which is of great importance, but one to which sufficient attention is not always paid in clearing forest land for rubber cultivation, is the necessity for burning the felled material as thoroughly as possible. Logs and stumps lying about a cleared area cost a large sum to remove, and if not removed prevent regular planting, hinder weeding and cultivation, harbour moles, and, it is believed, promote fungus attacks. Thorough burning consumes all logs and a good many stumps as well as the seed of weeds and climbers, prevents regrowth from felled trees, and enriches the soil with a deep layer of ashes ; it may mean all the difference between failure and success. The secret of this operation is to fell the trees soon after the rainy season is over, to cross-cut the felled material and allow it to lie through the cold and hot seasons, to protect the area carefully from fire meanwhile, and to burn well on in the hot season without risking too long a delay in case of rain. The felled material thus dries as thoroughly as time permits, and the result is a very severe conflagration which may consume it all, together with any regrowth and weeds which may have sprung up after the felling, and at least a portion of the stumps. It seldom happens, however, that all the felled material is completely consumed at the first burning, and it is generally necessary to collect the unburnt refuse and burn it again.

In India and Burma the growth of rubber trees is not as a rule equal to that in the Malay States, owing to the long dry season. It is therefore not generally considered advisable to commence tapping under six years from the time of planting. For the same reason planting is, as a rule, closer in India and Burma than in the Malay States. In the Government plantation at Mergui the spacing first tried was 12 ft. by 12 ft., but this was soon found to be too close, and from the third year onwards a spacing of 16 ft. by 16 ft. was adopted. Perhaps the most usual spacing is 20 ft. by 20 ft. rectangular ; this is sometimes effected by planting 20 ft. by 10 ft., and cutting out intermediate lines some years later. A spacing which has been adopted in some good estates is 18 ft. by 18 ft. in quincunx form. In the Andamans the oldest plantation was spaced 15 ft. by 15 ft., but this was found to be too close, and on flat ground the more recent plantations have been spaced 22 ft. on the triangular system, giving 104 plants per acre. On hilly ground the spacing adopted has been one of 15 ft. along contours 30 ft. apart, giving 96 plants per acre : the advantage claimed for this method is that it facilitates tapping on hilly ground.

YIELD. In India and Burma the industry is as yet young, and exhaustive figures of yield are not yet available. It was thought at one time that owing to the heavy rains of the monsoon alternating with a long dry season, rubber

planting in these countries would not prove remunerative. The yields derived so far in well-managed plantations, however, have dispelled such fears. One estate in Travancore has recently produced 150 lb. per acre from trees five years old, while two other estates have produced 360 and 326 lb. per acre from trees ten years old. In Burma it is generally estimated that an estate in full bearing should yield at least 350 to 400 lb. of rubber per acre per annum.

17. MANIHOT, Adans.

Manihot Glaziovii, Muell. Arg. Ceara rubber.

A moderate-sized tree with palmate leaves deeply cut into segments usually five to seven in number. Bark peeling off in horizontal strips like that of the cherry tree. The Ceara rubber tree is indigenous to the province of Ceara in Brazil, where it occurs in somewhat dry situations. It has been introduced into the East and thrives well in parts of Burma and Ceylon, growing in the latter country up to at least 3,000 ft. elevation and even on the most barren soils. It has succeeded well in Calcutta and Madras, and at Kushi in Assam. In the Forest compound at Tharrawaddy, Burma, there were some years ago several trees, which reproduced so freely that the thickets of young plants became a nuisance and were eradicated in 1903, together with a number of the older trees. It grows well in Bhamo and Myitkyina. In Napier's Park, Ganjam, Madras Presidency, it grows very well and reproduces freely; trees fourteen years old attained a height of 40 ft. and a girth of 24 in., but produced practically no rubber. A number of trees grown in Malabar were tapped experimentally in 1896 and 1897, but the yield was very poor.

So far as India is concerned, although the tree grows well in many places, and would probably thrive over a wider area than *Hevea brasiliensis*, the poor results obtained by tapping hitherto have not justified the formation of plantations.

In India the tree is leafless for some time early in the hot season, usually about February–March. The flowers appear in the cold season and the fruits ripen about March, opening and shedding the seeds round the trees. The seed has a caruncle at one end, and somewhat resembles that of the castor-oil plant in shape.

The testa is extremely hard, and germination is very slow unless the testa is filed almost through on either side of the caruncle. The plant is then easy to raise from seed, and it grows also from cuttings. The growth is very rapid, but the tree seldom reaches a height of more than 40 ft.

ORDER LIII. ULMACEAE (Urticaceae, tribes Ulmeae and Celtideae)

Genera 1. *ULMUS*, Linn.; 2. *HOLOPTELEA*, Planch.; 3. *CELTIS*, Linn.; 4. *TREMA*, Lour.

1. *ULMUS*, Linn.

There are five elms of the Indian region: (1) *U. Wallichiana*, Planch., the common elm of the western Himalaya; (2) *U. lancifolia*, Roxb., the eastern elm, found in Sikkim, Bhutan, Assam, Chittagong, and Burma; (3) *U. villosa*, Brandis (*U. laevigata*, Royle), the small-leaved elm of the Punjab Himalaya,

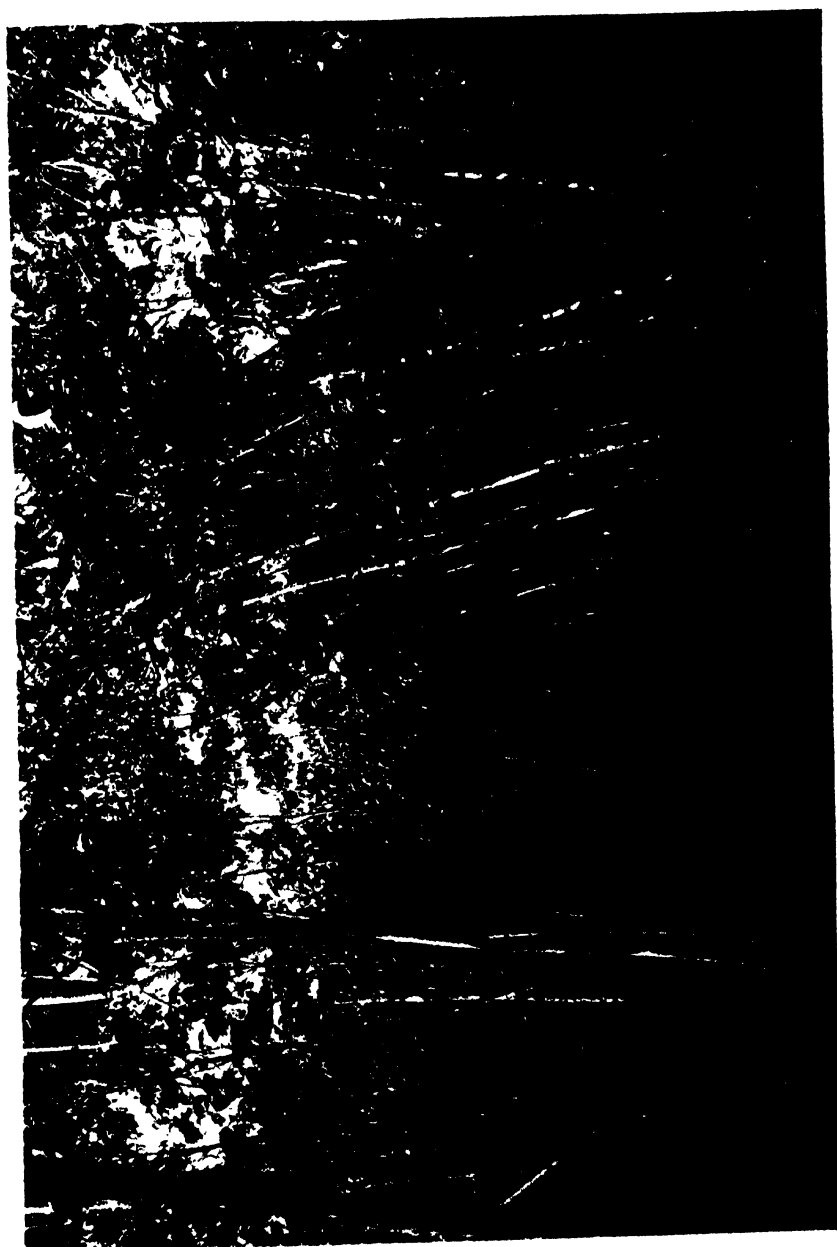


FIG 316. *Macaranga denticulata* raised by sowings in a savannah tract, South Muraghat forest, Jalpaiguri, Bengal, age 8 years, height 30-35 ft.

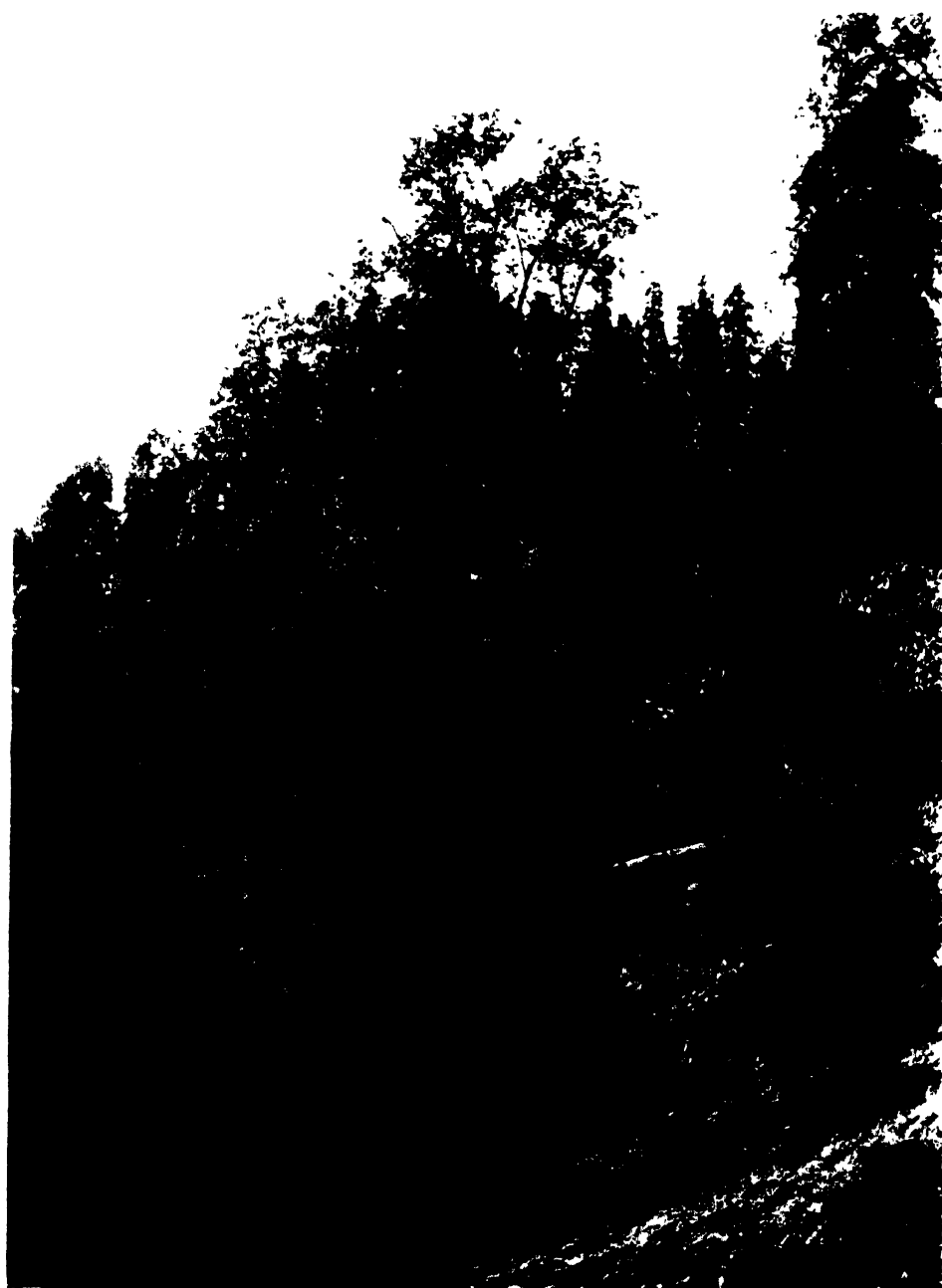


FIG. 317. *Ulmus Wallichiana*, Hazara.

closely akin to *U. campestris* ; it occurs at somewhat lower elevations than (1), ascending to 7,000 ft. ; it produces root-suckers freely ; (4) *U. campestris*, Spach., the common elm of Europe ; Baluchistan and Kurram valley at 7,000–9,000 ft. ; it produces root-suckers freely ; (5) *U. parvifolia*, Jacq. (*U. virgata*, Roxb.), an evergreen shrub, possibly wild in Nubra, northern Kashmir (Brandis).

Ulmus Wallichiana, Planch. The Western Himalayan elm. Vern. *Kain*, *marál*, *emroi*, W. Him. (Fig. 317.)

A large deciduous tree with rough grey thick bark deeply furrowed with longitudinal and diagonal furrows. The tree has a fine timber which deserves to be better known as a furniture wood. It reaches large dimensions ; Gleadow records one of 16½ ft. girth in Jaunsar, and Brandis one of 24 ft. girth. Large trees often have dry tops or become hollow.

This elm occurs throughout the western Himalaya from the Indus to Nepal at 3,500 to 10,000 ft. It is nowhere very common, but is found scattered in mixture with other trees, both conifers and broad-leaved species. It is found most commonly in fairly moist situations along the sides of ravines ; on dry ridges and at high elevations it is usually stunted. Natural reproduction sometimes springs up in abundance on newly exposed ground such as is found in cuttings and on embankments, landslips, the sides of ravines, and abandoned cultivation ; gregarious young crops have been noticed in Hazara on abandoned fields in the open. The tree is somewhat light-demanding, though it stands a little shade in youth. It does not produce root-suckers. It is often planted round villages and lopped for fodder. The tree is leafless during the winter months, the new leaves appearing about April–May. The flowers appear immediately before the new leaves, and the fruit, a membranous elliptical samara 0·6–0·7 in. long, ripens in May–June ; much of the seed is barren. The growth, according to Gamble, is slow ; of specimens examined by him the fastest showed 6 rings per inch of radius, giving a mean annual girth increment of 1·05 in.

2. HOLOPTELEA, Planch.

Holoptelea integrifolia, Planch. Syn. *Ulmus integrifolia*, Roxb. Indian elm. Vern. *Papri*, *papar*, *kanju*, *karanji*, *chilla*, *banchilla*, *kunj*, *bisenda*, Hind. ; *Rajáin*, Pb. ; *Wavuli*, *papara*, Mar. ; *Tapasi*, Kan., Tel. ; *Aya*, *avali*, Tam. ; *Myaukseik*, *pyaukseik*, Burm.

A large deciduous tree with strong ascending or spreading branches and elliptical leaves. Bark grey, fairly smooth. The bark when cut and the leaves and twigs when crushed have an offensive smell. Wood yellowish grey, strong, used for agricultural implements, and has been pronounced suitable for brush-backs.

DISTRIBUTION AND HABITAT. The sub-Himalayan tract from the Chenab eastwards, ascending to 2,000 ft., central India, Chota Nagpur, the Indian Peninsula, Upper Burma. It is commonly found in mixed deciduous forests of a somewhat dry type : Bourdillon says that in Travancore it is common in evergreen forests at low elevations. In the sub-Himalayan tract it is one of the largest and most characteristic trees at the foot of the outer hills and in the dry stony *bhabar* country flanking those hills, where there are thick boulder

deposits and water is at a great depth below the surface. Along the foot-hills it is found in association with *Adina cordifolia*, *Cassia Fistula*, *Schleichera trijuga*, and other species ; in places it springs up in great profusion and forms gregarious patches on the rocky débris along the lower slopes of the outer hills and on the dry stony ground at their base. Fig. 319 shows a group of large trees on a boulder deposit in the sub-Himalayan foot-hills ; the elm-like form is noticeable. In the dry *bhabar* tract its chief associates are *Hymenodictyon excelsum*, *Bombax malabaricum*, *Odina Wodier*, *Garuga pinnata*, *Lagerstroemia parviflora*, and *Acacia Catechu*. On poor shallow soil the tree becomes stunted and crooked. Haines¹ notes that there is a shrubby, stunted form common on the Palamau hills in Chota Nagpur.

• **LEAF-SHEDDING, FLOWERING, AND FRUITING.** In northern India the leaves fall chiefly in January and February, and the trees are leafless until April or May, when the new leaves appear. The fascicles of small greenish flowers appear on the leafless trees from February to April, and the winged fruits, hanging in clusters, ripen in April and May, when the trees are still leafless or the new leaves are appearing : the fruits fall soon after ripening and are carried by the wind to some distance from the tree. The samara (Fig. 318, a) is broadly elliptical or ovate, about 1 in. long ; about 700 to 800 fruits weigh 1 oz. Tests at Dehra Dun have shown that the seed does not retain its vitality long, though the percentage of fertility of good fresh seed may be high.

GERMINATION (Fig. 318, b-e). Epigeous. The radicle issues from the apex of the fruit and descends, while the hypocotyl elongates with slight arching and raises above ground the cotyledons, which are conduplicate until the hypocotyl has almost attained full length, when they unfold and expand, the young shoot appearing from between them.

THE SEEDLING (Fig. 318).

Roots : primary root long, terete, tapering, wiry, flexuose ; lateral roots numerous, fibrous, distributed down main root. **Hypocotyl** distinct from and thicker than root, 0.6-1 in. long, terete, tapering upwards, with a decided bend at the lower extremity formed during germination, white turning green, pubescent. **Cotyledons :** petiole about 0.05 in. long ; lamina 0.3-0.35 in. by 0.35-0.4 in., foliaceous, bifid to one-third or one-half the length, apices of lobes truncate or broadly rounded, base truncate, entire, finely pubescent, conduplicate in the seed. **Stem** erect, terete, zigzag at the nodes, green, pubescent ; internodes 0.3-1 in. long. **Leaves** simple, first pair opposite, subsequent leaves alternate. Petiole 0.05-0.1 in. long. Lamina 0.6-4 in. by 0.3-2 in., elliptical or ovate, acuminate, base cordate, serrate crenate, pubescent. The leaves of seedlings differ from those of adult trees in that the latter are normally entire.

Under natural conditions the growth of the seedling is at first slow, a height of only a few inches being attained by the end of the first season, but under favourable conditions the growth becomes fairly rapid subsequently. As a rule branching does not commence until the second season, and even then only in the case of the more vigorous seedlings. Weeding greatly stimulates development, while seedlings are liable to be suppressed and killed by a heavy growth of weeds. Good growth is attained only on porous soils, stiff soils preventing satisfactory development. Seedlings are sensitive both to frost

¹ For. Flora Chota Nagpur, pp. 389-90.

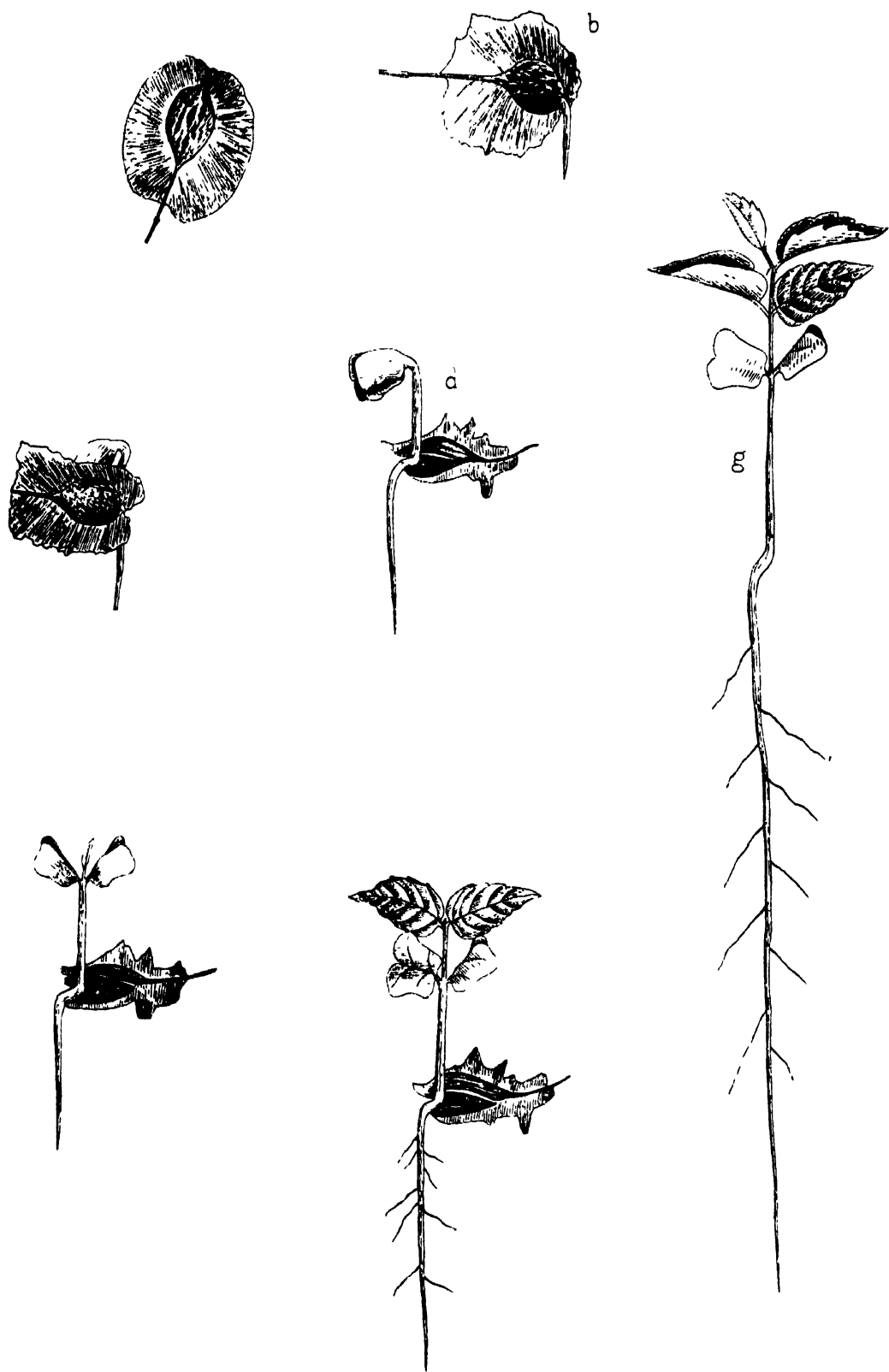


FIG. 318. *Holoptelea integrifolia*. Seedling $\frac{1}{2}$.
 a, winged fruit ; b-e, germination stages ; f, g, development of seedling during first season.

and to drought, and heavy mortality may be caused by both agencies ; if killed down to ground-level the young plants have little power of recovery.

The following measurements of seedlings grown in experimental plots at Dehra Dun give some indication of the rate of growth under different conditions :

Holoptelea integrifolia : rate of growth of seedlings at Dehra Dun.

Condition under which grown.	Height and other particulars at end of season.			
	1st season.	2nd season.	3rd season.	4th season.
(1) Natural conditions	Maximum 0 ft. 4½ in.	..	..	10-13 ft.
(2) Broadcast sowing, irrigated, unweeded	Maximum 0 ft. 4 in. (weakly)	Maximum 0 ft. 2½ in. (suppressed by weeds)	All killed by weeds in 3rd season	..
(3) Broadcast sowing, unirrigated, unweeded	Maximum 0 ft. 4 in.	Maximum 0 ft. 5 in. (suppressed by weeds)	0 ft. 3½ in.-0 ft. 4½ in. (suppressed by weeds)	..
(4) Broadcast sowing, unirrigated, weeded	Maximum 0 ft. 4 in.-1 ft. 3 in.	3 ft. 0 in. and 3 ft. 5 in. (Two survivors ; remainder killed by frost and drought)	6 ft. 2 in. and 7 ft. 7 in.	..

SILVICULTURAL CHARACTERS. The tree is a moderate light-demander. It requires good drainage, and is capable of thriving without much moisture in the soil, provided the soil is deep and porous. It produces a strong spreading root-system. It is not frost-hardy, and on the Punjab plains, where it is planted, it suffers considerably in years of severe frost. The leaves are not readily browsed by goats or cattle. The tree coppices, but there is no information available as to the extent of its coppicing power.

NATURAL REPRODUCTION. The seeds, which are distributed by wind during the hot season, do not as a rule germinate until the beginning of the rainy season ; if owing to abnormal rain germination takes place during the hot season the seedlings almost invariably perish of drought during the ensuing dry weather. In order to ensure successful germination and the survival of the seedling under natural conditions, it is important that the seed should fall on loose bare soil clear of weeds. This facilitates the covering of the seed with earth before germination takes place, an important matter in preventing the death of the germinating seedling from drought, while in addition the absence of weeds and the loose soil aid the development of the seedling, enabling it to establish itself and resist drought, which is perhaps the commonest cause of mortality. Some protection from the sun in early youth, such as is afforded by bushes and rocks, is beneficial. In the sub-Himalayan tract natural reproduction springs up in places in great profusion amongst the rocky débris on the lower slopes of the outer hills and on the dry stony porous ground along their base ; here may be found patches of almost pure forest containing plants of all sizes from small seedlings to mature trees. In Burma natural reproduction sometimes springs up readily on recently formed alluvial ground.

ARTIFICIAL REPRODUCTION. This species has been raised successfully at Dehra Dun both by direct sowing and by transplanting nursery-raised seedlings, the more vigorous plants in the first rainy season and the less vigorous ones a year later. In either case fresh seed should be sown soon after collection, about April or May, and lightly covered with earth. Stiff soil should be avoided and regular weeding and loosening of the soil should be carried out, whether in the nursery or in the plantation. In the nursery regular watering is neces-

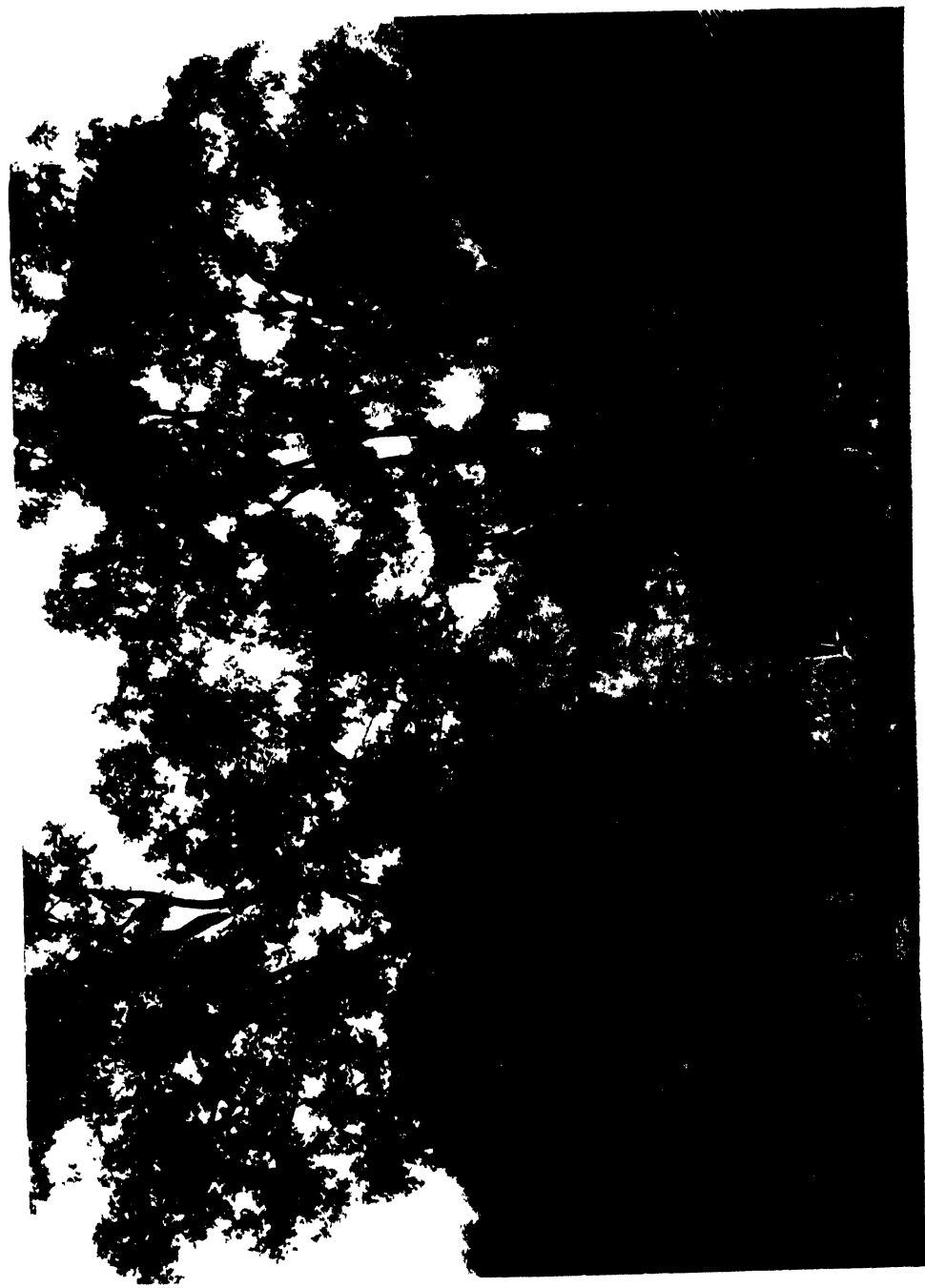


FIG. 319. *Holoptelea integrifolia*. trees in the Himalayan foot-hills, Kotdwara. United Provinces.



FIG. 320. *Ficus*-bound teak tree, girth over *Ficus* 17 ft 5 in.,
Toungoo, Burma

sary, and it has been found advisable to shade the beds during the heat of the day from the time the seed is sown until the rainy season has set in, otherwise there is considerable mortality from drought during and after germination.

RATE OF GROWTH. The growth is fast. Gamble states that it is usually about 6 rings per inch of radius, giving a mean annual girth increment of 1.05 in., but that it is sometimes as fast as 2 rings to the inch, giving a mean annual girth increment of 3.14 in. A cross-section from the United Provinces in the silvicultural museum at Dehra Dun had 93 rings for a girth of 7 ft. 1 in., showing a mean annual girth increment of 0.91 in.

3. CELTIS, Linn.

Four Indian species, of which the two most important are *C. australis*, Linn., of the western Himalaya, and *C. tetrandra*, Roxb., a large tree of the eastern Himalaya and the hills of the Indian Peninsula, particularly the Nilgiris, where it ascends to 7,000 ft.

Celtis australis, Linn. Syn. *C. caucasica*, Willd. Nettle tree. Vern. *Kharak*, *kharik*, *ku*. W. Him.; *Taghar*, Pushtu; *Batkarar*, Haz.; *Brimij*, Kashm.

A moderate-sized, sometimes fairly large, deciduous tree with variable ovate acuminate leaves oblique at the base and strongly 3-nerved. Bark smooth, bluish-grey, often with horizontal wrinkles and small round excrescences, much resembling that of the European beech. Wood tough, strong, and elastic, used for oars, tool-handles, and ploughs. The tree is much lopped for cattle fodder.

DISTRIBUTION AND HABITAT. Western Himalaya eastward to Nepal, ascending to 8,000 ft., hills of Afghanistan and Baluchistan, extending westward through southern Europe. It is often cultivated on the plains, where it grows well. In the Himalaya it is often found in forests associated with deodar and blue pine, and with horse-chestnut, maple, bird-cherry, oaks, and other broad-leaved species; it is also frequently cultivated round villages and regularly lopped for fodder. This tree is interesting as being one of those which ascend to fairly high elevations and also occur in swamp forests in the outer valleys below 2,000 ft. One of the best examples of its occurrence at a low elevation is to be found in the swamp forest at Sitabani near Ramnagar, where it grows gregariously.

LEAF-SHEDDING, FLOWERING, AND FRUITING. In the Himalaya the leaves are shed in December and January, and the new leaves appear in March or April. The small greenish flowers appear with the new leaves. The fruits form rapidly, attaining full size by June or July, though they remain green till September or October, when they become yellow. From October to December they turn black and become dry, falling to the ground during December and January; some are eaten on the trees by birds, including crows, by whose agency the seeds are spread. The fruit (Fig. 321, *a*) is an ovoid or nearly globose drupe, 0.3 in. long.

GERMINATION (Fig. 321, *b-g*). Epigeous. The putamen of the drupe splits into two parts, the radicle emerging from the under side of the fruit and the plumule through the upper side. The hypocotyl is arched at first, and in straightening raises above ground the cotyledons, which are conduplicate

in the seed, but soon unfold and expand. The remains of the fruit are left in or on the ground.

THE SEEDLING (Fig. 321).

Roots : primary root moderately long, thin, terete, wiry, flexuose ; lateral roots numerous, somewhat long, fibrous. *Hypocotyl* distinct from root, 0.8–1.4 in. long, terete, tapering slightly upwards, green, minutely pubescent in upper part, glabrous elsewhere. *Cotyledons* : petiole about 0.05 in. long ; lamina 0.4–0.6 in. by 0.35–0.4 in., foliaceous, oblong, cleft to nearly one-quarter of the length, base rounded or truncate or slightly auriculate, entire, green, minutely pubescent or glabrescent, conduplicate in the seed. *Stem* erect, terete, zigzag at the nodes, wiry, greenish brown, young parts green and pubescent. *Leaves* simple, first pair usually opposite, subsequent leaves alternate. Stipules 0.1 in. long or less, falcate, acuminate, pubescent, caducous. Petiole 0.1–0.2 in. long. Lamina 0.8–2.8 in. by 0.5–1.1 in., obliquely ovate, acuminate, base rounded or slightly cordate, serrate, basal portion entire, minutely scabrous, prominently 3-veined from the base.

The growth of the seedling is slow to moderate. Plants raised at Dehra Dun attained a height of 5 to 12 in. by the end of the first season, and 8 to 18 in. by the end of the second season. The seedlings were found to be frost-hardy but somewhat sensitive to drought.

SILVICULTURAL CHARACTERS. The tree stands a moderate amount of shade. It is not very exacting as to soil, growing both on swampy and on dry rocky ground, but in the latter case it becomes stunted. In India it is fairly frost-hardy ; the leaves are often affected by frost before they fall, but there is little or no permanent injury done. It pollards and coppices well.

ARTIFICIAL REPRODUCTION. Experiments at Dehra Dun showed that seedlings can be raised without much difficulty in the nursery, the seed being sown in February or March and the seedlings being transplanted in the first or second rainy season ; care is necessary not to expose the roots too much during transplanting.

SILVICULTURAL TREATMENT. In India the tree is regularly pollarded in village lands. In southern France it is worked in close-grown coppice mainly for the production of poles and whip-handles.

RATE OF GROWTH. The growth, according to Gamble, is moderate, about 8 to 9 rings per inch of radius, giving a mean annual girth increment of 0.7–0.78 in.

4. TREMA, Lour.

Species 1. *T. orientalis*, Bl. ; 2. *T. amboinensis*, Bl. ; 3. *T. politoria*, Planch.

1. *Trema orientalis*, Bl. Syn. *Sponia orientalis*, Planch. ; *S. Wightii*, Planch. Charcoal tree. Vern. *Jiban*, Beng. ; *Kargol*, *ranambada*, Mar. ; *Oman*, Tam. ; *Gada-nelli*, Tel.

A small, soft-wooded, fast-growing, and short-lived tree with straight spreading branches and ovate acuminate leaves usually with oblique bases. Bark thin, smooth, greyish green ; with numerous lenticels. The wood makes good gunpowder charcoal. Found throughout the sub-Himalayan tract from the Jumna eastwards, Bengal, Chota Nagpur, and the Indian Peninsula. It has a remarkable capacity for springing up on forest clearings, landslips, and wherever the ground is exposed ; in such places it is often the first tree to appear, coming up gregariously. It is thus a most useful plant for reclothing



FIG. 321. *Celtis australis*. Seedling $\times \frac{1}{2}$.
 a, fruit ; b-g, germination stages ; h-k, development of seedling to end of first season.

landslips and exposed ground. In the Dehra Dun valley it affects swampy places. In southern India it is often planted as a shade tree for coffee. The fruit is a small black drupe, 0.15 in. in diameter; the seed is possibly spread by birds, though this requires verification. The growth is very fast. Gamble mentions a tree cut by him at Sivoke, Bengal, which in five years had attained a height of 25 ft. and a girth of 40 in.

2. *Trema amboinensis*, Bl. Syn. *Sponia velutina*, Planch. Vern. *Kywea*, *satsha*, Burm.

This tree is nearly allied to the preceding species, and is perhaps not specifically distinct. It occurs in Sikkim, Assam, Chittagong, Burma, Andamans. It appears in abundance on abandoned *taungya* clearings in Burma. In the Andamans it sometimes comes up almost pure in *taungya* areas cleared for padauk sowing, and spreads in remarkable fashion; it is beneficial to young padauk if merely lopped or cut back to free the leading shoot of the padauk.

3. *Trema politoria*, Planch. Syn. *Sponia politoria*, Planch. Vern. *Kuri*, *khagshi*, *khardal*, *banharria*, Hind.

A small evergreen tree with scabrous leaves, which are used for polishing wood. Sub-Himalayan tract, Salt Range, Rajputana, Central Provinces, Chota Nagpur, Upper Burma. This tree, like the other two species, comes up in profusion on landslips, abandoned cultivation, cuttings, or embankments, and other places where the soil is exposed, as well as on sandbanks in the beds of streams and shingle deposits in dry river-beds. It is a useful species for binding the soil on landslips and similar places. The fruit is a small drupe, 0.1–0.15 in. in diameter.

The growth is rapid. Gamble gives 2 rings per inch of radius, representing a mean annual girth increment of 3.14 in.

ORDER LIV. MORACEAE (Urticaceae, tribes Moreae and Artocarpeae)

An important order, containing some valuable timber trees (particularly species of *Artocarpus*), rubber-yielding trees (*Ficus elastica* and the exotic *Castilloa elastica*), and fruit trees (*Ficus*, *Artocarpus*, and *Morus*). The important part which birds play in distributing seeds is strikingly illustrated in this order.

Genera 1. *FICUS*, Linn.; 2. *ARTOCARPUS*, Forst.; 3. *MORUS*, Linn.; 4. *BROUSSONETIA*, Vent.; 5. *CASTILLOA*, Cerv.

1. *FICUS*, Linn.

This is a very large genus, containing about 80, or perhaps more, Indian species, of which only a few of the commoner or more important are dealt with here. Economically by far the most important is *F. elastica*, the india-rubber fig, though the promise at one time held out by it has not been fulfilled owing to the successful introduction into the East of *Hevea brasiliensis*, the cultivation of which has proved far more profitable. Several of the wild Indian figs produce more or less edible fruits, and the true edible fig, *F. Carica*, is cultivated in India.

The habits of the figs vary. Many start life as epiphytes and remain as such for years or even throughout their life ; of these may be mentioned *F. gibbosa*, *F. bengalensis*, *F. elastica*, *F. retusa*, *F. Rumphii*, and *F. religiosa*. These epiphytic figs can, however, be grown as terrestrial trees. Many epiphytic species produce large aerial roots, which may interlace or may grow vertically downwards, taking root in the ground and enabling the crown of the tree to spread over a large area ; the most notable examples of aerial root production are to be found in *F. bengalensis* and *F. elastica*. Of species which are never epiphytic may be mentioned *F. hispida*, *F. Cunia*, *F. palmata*, *F. Carica*, *F. Roxburghii*, and *F. glomerata*. In addition there are certain small scandent species, for example *F. scandens*, *F. foveolata*, and *F. pumila*, the last named a Chinese species cultivated in India ; these are of no special importance in forestry, but are interesting from their habit of clinging like ivy to rocks, tree trunks, or walls by means of numerous small aerial rootlets. An interesting fact regarding the figs is the part played by minute hymenopterous insects in the fertilization of the female flowers, and possibly the natural distribution of each species of *Ficus* may be limited by the presence of the particular species of insect which effects its fertilization.

As far as observations go, the epiphytic figs, even when their roots become established in the ground, appear to possess no coppicing power when felled, though this statement requires verification. On the other hand, some at least of the non-epiphytic species have this power, while some, notably *F. hispida*, have the power of producing root-suckers.

The epiphytic figs are regarded as very troublesome pests in forest operations in India. The fruits are eagerly devoured by birds and the seeds are dropped by them in the forks and hollows of trees throughout the forest. The seedlings thus develop out of reach of danger, and as the plants grow they gradually send their aerial roots down to the ground and establish themselves, encircling and strangling their hosts, which are often valuable timber trees (see Fig. 320). The only preventive measure is systematically to fell these fig-bound trees, a costly operation, otherwise they become centres for the further spread of the fig. Opportunity is taken to remove such trees when felling for the market. It is interesting to note that in the abnormal drought of 1907 and 1908 in the forests of Oudh the epiphytic figs proved conspicuously drought-resistant.

Most if not all species of fig can be propagated by cuttings (see under *F. bengalensis* and *F. elastica*). They can be raised from seed only if special precautions are taken, since the seeds are very minute. The process of preparing the seed and raising seedlings, as described for *F. elastica*, is applicable generally to species of this genus. The main points to bear in mind are (1) to sow the seed in boxes or well-raised beds in very fine soil of sifted rich mould and sand, made specially porous towards the surface by a mixture of powdered charcoal or brick-dust, (2) to shade the beds or boxes from the sun and to prevent any drip from rain, (3) to keep them always moist by watering with a very fine spray. When large enough the seedlings are pricked out in well-raised open nursery beds, after which they give very little trouble.

Species 1. *F. gibbosa*, Bl. ; 2. *F. bengalensis*, Linn. ; 3. *F. elastica*, Roxb. ; 4. *F. retusa*, Linn. ; 5. *F. Rumphii*, Bl. ; 6. *F. religiosa*, Linn. ; 7. *F. hispida*,

Linn. f. ; 8. *F. Cunia*, Ham. ; 9. *F. palmata*, Forsk. ; 10. *F. Carica*, Linn. ; 11. *F. Roxburghii*, Wall. ; 12. *F. glomerata*, Roxb. ; 13. *F. pumila*, Linn. ; 14. *F. scandens*, Roxb. ; 15. *F. foveolata*, Wall.

1. *Ficus gibbosa*, Bl. Syn. *F. Ampelos*, Roxb. ; *F. tuberculata*, Roxb. ; *F. parasitica*, Koen. ; *F. excelsa*, Vahl. Vern. *Chanchri*, Garhwal ; *Majni, chirwal*, C.P. ; *Datir*, Mar. ; *Itthi*, Tam. ; *Nyaung thabye*, Burm.

An evergreen epiphyte, sometimes becoming an independent tree. Leaves variable, elliptical, smooth above, rough beneath (var. *tuberculata*) or broad sub-rhomboid, hispid above (var. *parasitica*). Bark smooth, greenish yellow to greyish brown. This is a much-branched fig with numerous interlacing aerial roots, and is often found completely embracing other trees, particularly other figs and *Adina cordifolia*, also clinging to walls. Widely distributed. Fruits 0.2–0.3 in. in diameter, ripening from February to May, yellow when ripe.

2. *Ficus bengalensis*, Linn. Syn. *F. indica*, Roxb. ; *Urostigma bengalense*. Gasp. Banyan. Vern. *Bor, bar, bargat*, Hind. ; *Wad*, Mar. ; *Al, alada*, Kan. ; *Ala*, Tam. ; *Pyinyaung*, Burm.

A very large evergreen tree, usually starting life as an epiphyte, with large spreading horizontal branches from which numerous aerial roots are thrown down, these taking root in the ground, growing into new trunks and helping to spread the crown of the tree. Leaves 4–8 in. long, elliptical or ovate, thickly coriaceous, shining. In dry localities the tree becomes leafless for a short time in the hot season, but ordinarily it is evergreen. Various records of large trees exist, and large specimens with a crown cover more than 200 ft. in diameter are by no means rare. The famous tree in the Royal Botanic Gardens, Calcutta, which was ascertained to have grown from a seed deposited in the crown of a date palm in 1782, had, according to Colonel Prain, quoted by Gamble, the following measurements in 1900 : circumference of the trunk 51 ft., of the crown 938 ft. ; height, 85 ft. ; number of rooted drops, 464. ' Mr. Warner, quoted by Sir G. King, describes a banyan at Wysatgarh near Satara which had in 1882 a circumference of spread of 1,587 ft., while another, in the Andhra valley near Poona, had a circumference of spread of about 2,000 ft.' (Gamble).

This tree is widely distributed through the forest tracts of India, and is extensively planted for shade in gardens and villages and along roadsides. It is a useful elephant fodder, and is lopped for this purpose ; in some localities the felling of the tree is forbidden within a mile of a camping ground, in order to ensure supplies of elephant fodder. In the forest, however, it is one of the most noxious of the epiphytic figs, occupying a large amount of space to the exclusion of useful species. The seeds, dropped by birds in the forks and boughs of trees, germinate there, and as the plant is fast-growing it soon envelops and kills its host and spreads by means of its aerial roots. It is extremely difficult to eradicate, owing to the tenacity of the roots and the large size of the tree. It is very destructive to walls and buildings, the roots penetrating the crevices and being difficult to eradicate.

The tree is decidedly drought-hardy, as was proved in the abnormal drought of 1907 and 1908 in the forests of Oudh. Severe frosts damage the leaves, but the tree shows good power of recovery, and did not suffer to any great extent in the abnormal frost of 1905 in northern India.

The fruits, which are red when ripe and 0.5–0.7 in. in diameter, ripen chiefly from March to May, but they may often be found at other seasons of the year. They are readily eaten by birds and monkeys and in times of scarcity by human beings.

The tree can be propagated from seed or from cuttings. The seed should be sown as soon as it ripens, preferably in pots or boxes in fine mould mixed with powdered brick or charcoal, and the young plants should be kept shaded in the heat of the day. Large cuttings 8 to 10 ft. high should be planted about January to March and well watered until the rainy season, or if watering cannot be carried out they may be put down at the commencement of the rains, though this is usually less successful. Small cuttings put down in pots or baskets in March and well watered sometimes prove successful.

3. *Ficus elastica*, Roxb. Indiarubber fig, Indian caoutchouc, Assam rubber. Vern. *Attah*, *bor attah*, *bor*, Ass.; *Nyaung kyetpaung*, Burm.

A very large handsome evergreen tree, with spreading branches and a dense crown of dark green shiny leaves; usually epiphytic in the natural state, sending down numerous aerial roots, and often much buttressed or fluted in the trunk. Leaves elliptical, coriaceous, shining, 5–10 in. long, with a prominent midrib, enclosed in the bud in terminal red stipular sheaths which fall as the leaves expand. Bark greyish or reddish brown, fairly smooth but scurfy. In its natural habitat the tree attains very large dimensions, a height of 100 to 120 ft. being not uncommon, while occasionally it reaches a height of 150 ft. or even more.

This, the most important indigenous rubber tree of India, at one time held out promise of being of great future value, and plantations of it have been formed on a fairly large scale in Assam. The extensive plantations of Pará rubber in the East, however, have sealed its doom as a commercial proposition, for Pará rubber comes into bearing much sooner than Assam rubber, and, age for age, produces higher yields per acre. It is more than doubtful, therefore, if the plantations now in existence can claim to be a commercial success, though this was not foreseen when the majority of them were formed, and *Ficus elastica* has accordingly been entirely discarded by planters in the East in favour of *Hevea brasiliensis*.

DISTRIBUTION AND HABITAT. The outer Himalaya from Nepal eastwards, ascending to 5,000 ft., Assam, Khasi hills, Hukong valley and other valleys of Upper Burma, ascending to nearly 5,000 ft., and extending south to just below the 20th parallel of north latitude in the Minbu district.

In Assam the tree is most plentiful in the Darrang and Lakhimpur districts; it was at one time found in considerable quantity in Bhutan, the Naga hills, and the Akah and Daphla territories, while Mr. Milroy¹ notes its occurrence in the Abor country. In tribal territories there is reason to fear that it has largely disappeared through excessive tapping. Mr. Jacob² notes that in Bhutan it has for this reason almost disappeared from the forests west of the Manas river, while east of that river it is still fairly plentiful, though he observed numbers of dead trees killed by excessive tapping. It is a conspicuous tree in the evergreen forests of Assam, often towering over the

¹ Report on the Forests of the Abor country, 1912.

² Report on the Forests of Bhutan, 1912.

surrounding forest : it occurs scattered and not gregariously. In his report on the Hukong valley of Upper Burma, Mr. H. N. Thompson mentions that the tree is found scattered generally through the dense evergreen forests, a mature tree being found every 200 or 300 yards in the richer forests. In Upper Burma the tree does not ordinarily extend south of 24° N. lat., but Mr. W. T. T. McHarg¹ found it in limited quantity in the drainages of the Pani, Maton, and Kyaungtha streams in the Minbu district just south of 20° N. lat. He notes that it always starts life as an epiphyte, and that the trees in that locality are always found near water, the roots forming a regular lace-work over the bank and running down into the bed of the stream.

The chief factor which determines the natural distribution of the tree appears to be excessive humidity, which also denotes an equable climate ; actually it is found typically in warm steamy localities, though it ascends to altitudes which are moderately cool, and where fairly severe frost must almost certainly be encountered. Its commonest situation is in damp valleys, and on the sides of gorges and moist hill slopes ; it is capable of accommodating itself to different types of soil, but requires good drainage.

Apart from the plantations which have been formed in Assam and elsewhere, the tree is often cultivated as an ornamental or shade tree, and thrives well in many localities outside its habitat. It shows very fair growth at Dehra Dun, and is even grown as a shade tree in Egypt. It is familiar as a pot plant in houses in Britain.

FRUITING. The fruits are greenish yellow to red when ripe, ovoid, about 0.4–0.5 in. long, sessile in pairs at the nodes, and containing numerous small seeds. The fruits commence ripening in May, and continue ripening and falling throughout the rainy season and sometimes onwards until December ; some trees shed all their fruits by the end of June. The fruits are eagerly sought after by birds, and the greater part of the crop is often devoured on the tree. Claud Bald² says the best seed is obtained in the hottest months—May, June, and July. Seed should not be collected except from fruits which are thoroughly ripe and soft, and should be used quite fresh. The ripe fruits, when collected, should be divided in two with the fingers, spread out to dry in the sun, and then rubbed into powder between the hands ; the powder containing the seeds should then be sown. If the seed has to be sent to a distance it should be mixed with charcoal dust to assist it in retaining its vitality.

GERMINATION AND DEVELOPMENT OF SEEDLING. Germination is epigeous. The following description of the seedling is by Rai Bahadur U. N. Kanjilal³ from specimens raised at Dehra Dun (see Fig. 322) :

‘ At first a pair of cotyledonary leaves appear, which are about one-tenth inch in diameter, orbicular-ovate emarginate, dull green, minutely petioled. Above these come out a pair of opposite leaves. These are stipulate (as are all succeeding leaves), slightly crenate, distinctly emarginate, membranous, with faint indications of arcuate nerves at the sinuses of an intramarginal vein, very shining above, until superseded by the next leaf ; one of the two leaves is somewhat larger than the other. Above these the leaves are sub-opposite when they appear, but soon become distinctly alternate by the elongation of the stem, each succeeding one larger in size than the one next below, second

¹ Ind. Forester, xxi (1895), p. 389.

² The Cultivation of *Ficus elastica*, 1906.

³ Ind. Forester, xxv (1899), p. 64.

much brighter, especially when fully grown. The fourth leaf above the cotyledons is about 1 by 6 in., ovate, distinctly crenate, emarginate. The next two leaves, the fifth and sixth, are oblong, 2 to 2.5 in. long, still emarginate, but the crenations are very shallow in the last leaf; lateral nerves four to six pairs, slightly arcuate. Then comes out the seventh leaf, all by itself, 3 by 1.2 in., oblong, with six to eight pairs of parallel nerves and two to three intermediate ones between, no longer emarginate, but acute and almost entire,



FIG. 322. *Ficus elastica*. Seedling $\frac{1}{2}$. (After Kanjilal.)

a, about ten days old; b, about one month old; c, about six weeks old.

with a row of white glandular dots along the margins. This is the first leaf that reveals the identity of the plant. Beyond this the leaves become thicker and thicker, the eleventh being about as thick as a normal India-rubber leaf. By the time the fifth leaf appears, a swelling is noticed below the root-collum, which goes on increasing in size.

As the seedling increases in size the bulbous swelling gradually disappears.

SILVICULTURAL CHARACTERS. Although the tree grows naturally among evergreen shade-bearers it exhibits decided light-demanding tendencies. Thus

the seeds brought by birds germinate in the summits of tall trees, and the young plants develop in the enjoyment of an abundance of light ; they find nourishment in the débris which lodges in the forks and hollows of the tree and for some years grow purely as epiphytes, sending down aerial roots which eventually reach the ground and establish themselves. Thereafter the tree increases in size, producing numerous fresh aerial roots and eventually killing its host. The absence of young plants of terrestrial origin under the forest canopy is given as a reason, and no doubt a valid one, for concluding that the tree is a light-demander. A note in the *Indian Forester*, vol. xxiii (1897), p. 369, maintains that in order to permit the young plant to establish itself and to become sufficiently strong to form a connexion with the soil below, it is absolutely necessary that the tree on which it finds itself placed should be either dead or diseased ; if not, the young plant cannot obtain sufficient nourishment, and dies. That this is the case, the note continues, has been clearly established by experiments in the Charduar rubber plantations, where many hundred plants were planted in the forks of trees. They were supplied with a considerable quantity of soil and grew to be healthy plants, but they lived the life of pot plants, and after more than ten years not one of those growing on a healthy tree had established its connexion with the soil.

The terrestrial roots of the rubber tree are superficial, and form a dense network along the surface of the ground, often spreading to a distance of 150 ft. or more from the tree. These roots have a remarkable power of anastomosing, and all the trees of a plantation may have their roots so amalgamated that the plantation becomes virtually one extensive tree. The aerial roots also exhibit a strong tendency to anastomose.

Although in its natural state the tree extends into regions of frost, the young plants, situated high up in trees, probably escape severe frost. At Dehra Dun trees grow well and appear to be unaffected by the annual frosts of that place. Trees planted at Shillong were killed during the abnormal frost of 1905, which, however, also killed large numbers of indigenous trees.

In plantations rubber plants suffer much from the depredations of wild elephants and deer ; in their natural epiphytic state they escape this form of damage owing to their elevated position.

ARTIFICIAL REPRODUCTION. The tree may be propagated either by transplanting nursery-raised seedling plants or by means of cuttings or layers. The latter method has long been discarded for plantation work in favour of transplanting seedling plants, which are found to produce aerial roots more prolifically and also to be more hardy. Plants raised by cuttings or layers, however, may be conveniently employed in planting avenues or single trees for shade or ornament. The various methods of raising plants and transplanting may be described briefly.

Nursery treatment. In Assam the usual time for sowing is the rainy season, from June to September, as rapid germination takes place at that time. Seed-beds 3 to 3½ ft. wide should be formed of light pulverized sandy loam, not of stiff soil, and should be raised several inches and kept from collapsing at the sides by walls of reed-work supported by stakes. The surface soil should be well mixed with powdered charcoal and flattened down to a smooth surface. The minute seeds, dried and prepared as already described, are

mixed with about two to five times their weight of sifted wood-ash and five to ten times their weight of fine mould, the mixture being spread evenly over the surface of the bed and flattened down. According to Mr. D. P. Copeland,¹ 4 to 6 lb. of seed should suffice for a seed-bed 40 ft. by 3½ ft.; with good germination this should yield 2,000 seedlings and should be sufficient to plant up 100 acres of rubber 70 ft. by 35 ft.

Shading of the beds is essential. The shades, made of thatch, should be made to slope towards the south, and should be high enough to admit a fair amount of light and thick enough to prevent rain dripping through. These shades may be removed during dull weather after the seedlings are sufficiently strong, and should be dispensed with altogether for some weeks before the young plants are removed from the nursery. The beds should be regularly watered from the commencement, and should never be allowed to become dry; excessive watering, however, causes the seedlings to damp off, and should be carefully avoided. The soil should be kept free from weeds and periodically loosened to prevent caking.

Sowing in seed-boxes or pans as a rule gives better results than sowing in open beds, the soil and the method of sowing being otherwise the same. A covering of glass over the boxes is sometimes recommended in order to force germination.

When about 2 in. high the seedlings are pricked out about 1 ft. by 1 ft. in nursery lines, in well-raised beds. In the Assam plantations it has been customary, owing to the risk of damage by deer and wild elephants, to remove the plants in the following rains, when about 1–2 ft. high, to stockaded nurseries in the forest, where they are planted 5 ft. by 5 ft. on well-raised beds; they are kept there until they are 10 to 12 ft. high, by which time they are about three years old, when they are dug up, the roots are trimmed where too long, and the saplings are finally planted out on mounds.

Transplanting. Some care is necessary in selecting the site for a plantation. Swampy or badly drained ground should be avoided. Well-drained high ground is the most suitable, but alluvial flats, if well drained, are also good. Soil consisting of little except sand and shingle is said to produce poor yields. Since a fair degree of atmospheric and soil moisture, and protection from the desiccating effect of the sun, are essential to the best growth, plantations in Assam have been formed by clearing lines through existing forest in a direction from east to west, a belt of forest being left between the lines to afford side shade in the heat of the day. The most suitable spacing has been the subject of some debate at various times. In the earlier plantations lines 40 ft. wide were cleared 100 ft. apart from centre to centre, leaving a 60 ft. belt of forest between the lines, and the plants were spaced 25 ft. apart along the lines. This spacing was found to be too close, and from 1893 onwards the lines were cut 70 ft. apart from centre to centre and the plants were spaced 35 ft. in the lines. In the Kulsi plantation spacings first of 100 ft. by 25 ft., later of 50 ft. by 25 ft., and finally 25 ft. by 25 ft. have been adopted. Few figures are available showing to what extent the spacing affects the yield of rubber, but such as they are they show that very wide spacing produces less rubber per acre than moderately close spacing. This being so, complete

¹ Ind. Forester, xxiii (1897), p. 420.

clearing and planting would seem to be preferable to partial clearing in lines, not only in producing higher yields but also in avoiding the high cost of keeping the belts of forest from encroaching on the lines.

The actual planting is carried out on mounds of varying size, usually 4 ft. high with a basal diameter of 10 ft. sloping to a diameter of 4 ft. at the top. In the centre of each mound a stout stake about 20 ft. long is planted, and to it the sapling is tied to keep it from being blown down or pulled down by deer or monkeys. In the case of large plants it is preferable to plant early in the rains, but small plants bear transplanting at most seasons of the year.

Attempts have been made to plant seedlings in soil placed in the forks and hollows of trees or in hollow stumps, but these have in most cases resulted in failure.

Subsequent tending. Frequent cleanings are necessary in the early years of the plantation, and vacancies have to be filled, while at that time as well as subsequently the belts of forest between the lines of plants require to be kept from encroaching on the lines by felling or girdling all threatening trees.

Cuttings and layers. The tree can be propagated by cuttings or by layers. Cuttings should be made from young branches in which the wood has become thoroughly lignified, and not from tender young shoots. They may be planted in nursery beds any time from February till May, and should be shaded from the sun in the heat of the day and regularly watered. It is advisable to keep them in the nursery for at least a year, and preferably for two years, before planting out.

Rooted cuttings or *gooties* can be propagated very successfully. In this case branches about 5 to 10 ft. long are selected, and at a point where the wood is thoroughly lignified the bark is removed all round the branch to a length of 3 or 4 in., care being taken not to injure the wood. The wound is covered with a ball of clay which is bound round with moss, grass, or sacking, and kept moist. In time rootlets are formed at this point, and make their way through the clay. The branch is then sawn off some inches below the wound and planted out.

Assam plantations. The most important plantations in Assam are the Forest Department plantations of Charduar in the Darrang district and Kulsi in the Kamrup district, both commenced in 1873. The expenditure during the earlier years was high, the work being largely experimental, but after experience had been gained it was found possible to bring the cost of stocking an acre with young established plants to between 40 and 50 rupees. Financially these plantations have proved a failure. In 1912 in the case of the Charduar plantation, the area of which was then 2,746 acres, the total cost, with interest to date, worked out at Rs. 9,83,633, the receipts with interest amounting to Rs. 3,13,295, leaving a debit of Rs. 6,70,338. In 1917 the area of the Charduar plantation was 2,904 acres, and that of the Kulsi plantation was 160 acres.

RATE OF GROWTH. The rate of growth is rapid. The following statement gives a summary of numerous measurements recorded from time to time in the Assam plantations :

Ficus elastica : rate of growth in Assam plantations.

Age. years.	Mean height.		Mean girth.	
	Charduar. ft.	Kulsi. ft.	Charduar. ft.	Kulsi. ft.
5	23	25	1.4	1.4
10	43	46	4.5	3.4
15	61	66	8.5	5.4
20	75	82	12.9	8.0
25	87	95	17.4	12.4
30	98	106	22.0	

The faster height increment and the slower girth increment in Kulsi as compared with Charduar is due to the fact that the planting was closer in the former than in the latter.

Girth measurements vary much owing to the production of aerial roots, which tend to anastomose round the main stem. These roots account to a large extent for what appears from the figures to be phenomenal girth increment.

TAPPING. Careful experiments have shown that even moderate tapping carried out annually soon results in the death of the trees tapped. In the Assam plantations a system of tapping once in three years has been adopted, and so far this has not proved to be excessive. Tapping is carried out by means of horizontal cuts made with a V-shaped gouge 15 in. apart on alternate sides of the stem and main branches and extending from half to two-thirds the distance round. The latex flows for two or three minutes after tapping ; some of it coagulates in the cuts and is collected from them, and the remainder falls on mats spread below the trees. The tapping season in Assam is from the middle of October to the end of March. On no account should the terrestrial roots be tapped, as is done by collectors of wild rubber, since this kills the tree ; aerial roots of large size which have developed into separate stems may, however, be tapped. The age at which tapping should commence has not yet been accurately determined in Assam. The yield from small trees up to 3 or 4 ft. in girth is so small as to make it hardly worth while tapping them. It has generally been held in Assam that regular tapping should commence at about twenty years more or less, though the size of the tree rather than the age determines the time for starting. Under favourable conditions of growth and with light and careful tapping, however, trees may be tapped some years earlier. Reports in recent years have shown that the Assam system of tapping is not altogether satisfactory owing to the injury inflicted on the trees, and possibly further experiments in tapping by pricking, suction, or other methods may yet reveal a better system.

YIELD. The results of tapping in the Assam plantations have been so variable that it is difficult to obtain reliable average figures of yield. In 1912 it was estimated that the average yield for the previous ten years was 20.7 lb. per acre per annum in Kulsi with 66 trees per acre tapped, as against 8.9 lb. per acre per annum in Charduar with 13 trees per acre tapped. The trees tapped probably varied from twenty to thirty-five years of age. The variation from year to year may be illustrated from the fact that in Charduar in 1909-10 a yield of 37.3 lb. per acre was obtained over the area tapped as against 18.1 lb. per acre in the preceding year ; normally the area tapped is only

one-third of the total area of the plantation, since trees are tapped once in three years, so that these figures require to be divided by three in order to compare them with the averages given below. Variations are no doubt due partly to physical causes, but they are also due in large measure to the manner in which the control of operations is carried out under successive managers. The Assam plantations have not yet come into full bearing, and it is therefore difficult to estimate what their eventual yield will be. Based on the experimental tapping of natural trees it is believed that a fair average yield for trees fifty years old may be estimated at 10 lb. per tree for a season's tapping, while the yield from younger trees, say twenty to thirty years old, may be estimated at from 8 oz. to over 2 lb. per tree. It is said that in Sikkim a yield of 40 lb. per tree used to be common under the excessive system of tapping wild trees which was in vogue until the trees were killed out by over-tapping.

The yields from the Assam plantations compare very unfavourably with that reported by Berkhout¹ to have been obtained in a private plantation in the province of Kranong in the west of Java. This plantation was formed in 1872 on abandoned coffee land, the trees being planted 8½ yds. apart with 72 trees per acre. The total area amounted to 72½ acres, containing 5,200 trees. Tapping commenced when the plantation was fourteen years old; the yield after seven years' tapping showed an average of 71 lb. per acre per annum, and the plantation was found to have produced a net money yield of £1 12s. 10d. per acre per annum since its establishment.

4. *Ficus retusa*, Linn. Syn. *F. nitida*, Thunb. Vern. *Barri*, Kumaun; *Jamu*, Nep.; *Nandruk*, Mar.; *Pilala*, Kan.; *Ichi*, Tam.; *Yerra juvi*, Tel.; *Nyaungôk*, Burm.

A large handsome evergreen, usually epiphytic, tree with a dense shady crown of rather small dark green leaves. Bark dark grey, smooth. Aerial roots slender.

Distributed throughout the sub-Himalayan tract from the Siwaliks near Dehra Dun eastwards, Assam, Chittagong, Burma, Andamans, Chota Nagpur, and the Indian Peninsula. It is found most commonly in moist ravines. It is often planted for shade or ornament, and makes a particularly handsome avenue tree. This is one of the most frost-hardy species of *Ficus*; in the abnormal frost of 1905 it remained unaffected in the Agri-Horticultural Gardens at Lahore, where other species suffered, some badly. It may be propagated in the manner described for *F. bengalensis*. In Dehra Dun the fruits commence ripening about December and continue ripening for some time; they are 0.2-0.3 in. in diameter, sub-globose, yellowish or pinkish when ripe.

5. *Ficus Rumphii*, Bl. Syn. *F. cordifolia*, Roxb. Vern. *Pilkhan*, *khabar*, Hind.; *Pair*, *ashta*, Mar.; *Nyaungbyu*, Burm.

A moderate-sized to large, often epiphytic, almost deciduous tree, with oblong, ovate or broad ovate acuminate leaves. Bark yellowish grey, smooth. This tree is sometimes mistaken for the pipal (*F. religiosa*), the leaves being somewhat similar; it is a smaller and less handsome tree than the latter, the acumen is not so long, and the petioles are stouter and less flexible.

Distributed throughout the sub-Himalayan tract and outer hills, ascending to 5,000 ft., Assam, Bengal, Chota Nagpur, the Indian Peninsula, and

¹ Ind. Forester xxiv (1896), p. 100.

Burma. It is often grown on roadsides. In the forest it is frequently epiphytic, and may be classed as one of the noxious figs which strangle and kill their hosts. The fruits commence ripening about February-March, and continue ripening for some time; they are about 0.5 in. in diameter, globose, sessile in axillary pairs, blackish when ripe. The new leaves appear about March, by which time most of the old ones have fallen.

6. *Ficus religiosa*, Linn. Pipal. Sans. *Pippala*. Vern. *Pipal*, Hind.; *Aswat*, Beng.; *Ashvatha*, Mar.; *Arali*, Kan.; *Ragi*, *ravi*, Tel.; *Arasi*, Tam.; *Nyaung bawdi*, Burm.

A large tree, evergreen or nearly so, epiphytic when young, with spreading branches. Leaves broadly ovate, with an acumen 1 to 3 in. long, glabrous and shining, and a slender petiole which causes the leaves to oscillate readily in a breeze. Bark grey, smooth, exfoliating in irregular rounded flakes.

Indigenous in the sub-Himalayan tract, and wild if not indigenous in other localities; largely planted and run wild throughout India and Burma; rare in the arid region of north-western India. It makes a good avenue tree. This is the Bodhi tree under which Buddha sat and received enlightenment at Budh Gaya; it is one of the most sacred trees of India, is venerated both by Hindus and by Buddhists, and is often planted near temples and wells. Hindus have a strong religious objection to felling it. In the forest it is a destructive epiphyte, and it also does much harm to buildings and walls, sending its roots into crevices in them. It is often lopped for elephant and cattle fodder.

The tree grows fast and is easily raised from seed sown in boxes in fine mould mixed with powdered charcoal. It can be propagated from cuttings, but these do not strike so well as those of *F. bengalensis*. In the abnormal drought of 1907 and 1908 in the forests of Oudh the pipal proved to be conspicuously hardy; this was also found to be the case in the severe drought of 1899 and 1900 in the Indian Peninsula. It is frost-hardy, and was only slightly affected in the severe frost of 1905 in northern India.

In northern India the new leaves appear about December, by which time most of the old leaves have fallen; the young leaves are usually reddish. The fruits ripen from March to June, occasionally again later; they are depressed, globose, about 0.5 in. in diameter, sessile in axillary pairs, dark purple when ripe. They are eagerly devoured by birds and are a favourite food of the green pigeon.

7. *Ficus hispida*, Linn. f. Syn. *F. oppositifolia*, Roxb. Vern. *Dadūri*, *kagsha*, Hind.; *Kala-umber*, Mar.; *Chona atthi*, Tam.; *Kadut*, Burm.

A small to moderate-sized tree with opposite leaves 4-12 in. long, scabrous above. Not epiphytic. Common in many parts of India and Burma, usually in shady places and along ravines. It coppices and produces numerous root-suckers. The fruits are about 1 in. long, pale green when ripe, usually clustered on leafless, often drooping branchlets; they ripen at most seasons of the year. This tree has been introduced by canal water into the Changa Manga plantation near Lahore, where it suffers much from frost.

8. *Ficus Cunia*, Ham. Syn. *F. conglomerata*, Roxb. Vern. *Khunia*, *khain*, *khini*, *jarhphali*, Hind.; *Yekañ*, Burm.

A small or moderate-sized usually evergreen tree, sometimes leafless in

the hot season, easily recognized from its short-petioled semicordate or semi-sagittate rough leaves. Not epiphytic. The fruits are 0.5–0.7 in. long, clustered on usually leafless drooping branches, often several feet long, issuing from the stem, often near the root, and from the larger branches. The tree is distributed throughout the greater part of India and Burma, and is common particularly on the sides of ravines, and along watercourses and moist shady banks and cuttings. The fruits commence ripening about March, and continue ripening almost throughout the year.

9. *Ficus palmata*, Forsk. Syn. *F. caricoides*, Roxb. ; *F. virgata*, Roxb. Vern. *Pheru*, *phedu*, *khemri*, *anjiri*, Hind.

A moderate-sized tree with orbicular-ovate, sometimes deeply palmately-lobed leaves. Not epiphytic. A common species in the outer Himalayan ranges and valleys, extending eastward to Nepal and ascending to 7,000 ft., occasionally higher ; also in Baluchistan, the Suliman and Salt ranges, Mount Abu, and the hills of Merwara. This is a common species in the outer Himalaya, often on somewhat dry hill-sides. It extends some distance into the plains, usually along watercourses, which indicates that the fruits or seeds are washed down the streams from the hills, since the tree is essentially a hill species. The fruits are sub-globose or pyriform, 0.5–1 in. in diameter, yellow when ripe ; the fruit ripens from May to October. The fruits are eaten ; this species, indeed, is closely allied to the edible fig, *F. Carica*, Linn. In the hills the tree is lopped for cattle-fodder.

10. *Ficus Carica*, Linn. Fig. Vern. *Anjir*, Hind.

A moderate-sized deciduous tree with cordate more or less deeply lobed leaves. Not epiphytic. This is the well-known edible fig. It is believed to be indigenous to Baluchistan, Afghanistan, western Asia, and the eastern Mediterranean region. It is cultivated in these regions as well as in southern and western Europe, including the warmer parts of England. It is cultivated in northern India, both in the plains and in the outer hills up to about 5,000 ft., and in the Deccan, especially round Poona, where it yields excellent fruit. In India the fruit ripens as a rule from May to August. The tree is grown from cuttings, which are kept in shaded nursery beds until well rooted and then planted out. It grows best in rich soil in irrigated gardens. The fruit requires protection, while ripening, from birds, fruit bats, and insects ; small baskets are sometimes fixed round the fruits for this purpose.

11. *Ficus Roxburghii*, Wall. Syn. *F. macrophylla*, Roxb. Vern. *Timla*, *timal*, Hind. ; *Sinthapan*, Burm.

A moderate-sized handsome spreading evergreen tree with large broadly ovate, cordate or rounded leaves, sometimes as much as 1½ ft. in length and 1 ft. in breadth. Not epiphytic. The large fruits appear in large clusters on short leafless branches issuing from the trunk, often near the ground, and from the larger branches. The tree is indigenous to the sub-Himalayan tract and outer Himalaya, Assam, Chittagong, Burma, Chota Nagpur, and Orissa, and is sometimes cultivated for ornament and for the sake of its edible fruits. It is found most commonly in moist places and along streams. It is not very frost-hardy, and was badly damaged in the Agri-Horticultural Gardens, Lahore, during the abnormal frost of 1905. The fruits usually ripen from March to June.

12. *Ficus glomerata*, Roxb. Syn. *F. Chittagonga*, Miq. Vern. *Gular*, *umar*, Hind. ; *Umbar*, Mar. ; *Atti*, Tel. ; *Thapan*, *ye thapan*, Burm.

A moderate-sized to large deciduous tree with a spreading crown. Not epiphytic. Leaves ovate or elliptical lanceolate. Bark reddish brown, smooth, with occasional large cracks.

A common forest tree throughout the greater part of India and Burma, as a rule in moist localities along the banks of streams, the sides of ravines, and similar places. In the Dehra Dun valley it is a common constituent of swamp forests in association with *Eugenia Jambolana*, *Cedrela Toona*, *Pterospermum acerifolium*, *Albizia procera*, *Trewia nudiflora*, *Diospyros Embryopteris*, and *Putranjiva Roxburghii*. It is, however, by no means confined to low-lying moist ground, but may be found, sometimes almost gregariously, on rocky hill slopes, and is often found sporadically in sal forest and mixed forests of various types. It is often preserved round villages for the sake of its fruit, and is frequently cultivated.

The tree appears to shed its leaves at different seasons. In some localities the leaves are shed early in the cold season, the new leaves appearing from December onwards. Gamble notes that in some localities (Dehra Dun, Mysore) it is deciduous in the middle of the rainy season about August. The fruits are sub-globose or pyriform, 1-1.5 in. in diameter, red when ripe, in large clusters on short leafless branches emerging from the trunk and main branches ; they ripen chiefly from March to July. They are edible, but are usually too full of insects to be agreeable. They are a favourite food of monkeys, and when they fall to the ground they are greedily eaten by deer.

The tree is not very frost-hardy, and suffered in northern India in the severe frost of 1905. It coppices, but the growth of coppice-shoots appears to be slow, judging from the following results of measurements made in 1910 by Mr. C. M. McCrie in Gorakhpur, United Provinces :

Ficus glomerata : coppice measurements, Gorakhpur.

Age.	Mean height.	Age.	Mean height.
years.	ft.	years.	ft.
2	5.2	10	8.7
4	7.1	12	8.9
6	8.0	14	9.1
8	8.5		

13. *Ficus pumila*, Linn.

A Chinese species of small climbing fig frequently cultivated on walls in India, and sometimes popularly termed 'ivy', owing to its habit of climbing by large numbers of small aerial rootlets which cling tenaciously to walls like those of the true ivy. This fig grows fairly rapidly, covering the walls of a house in a few years with a dense growth of dark green foliage. The leaves of the barren climbing stems are much smaller than those of the fruiting branches ; the fruit itself is 2-3 in. long. The plant is easily grown from layers or from cuttings planted in pots and kept in the shade and watered until they have established themselves ; it grows better on cool northerly walls than on hot southerly ones.

14. *Ficus scandens*, Roxb. ; 15. *Ficus foveolata*, Wall.

Of scandent habit, similar to the preceding, climbing over moist rocks and tree trunks in shady places in the sub-Himalayan tract and outer Himalaya.

2. ARTOCARPUS, Forst.

This genus comprises eight Indian species, of which some are important timber trees or fruit trees. The breadfruit tree, *A. incisa*, Linn. f., a native of the South Sea islands, is cultivated to some extent in the tropical parts of India. The trees of this genus are somewhat shade-bearing, especially in youth; in their natural state they are all found in moist, usually tropical forest, sometimes in deciduous but usually in dense evergreen types. They bear fleshy fruits and rather large seeds which perish quickly. The fruits ripen as a rule early in the rainy season, and are eagerly devoured by birds or animals, the seeds being scattered beneath and around the trees or removed to some distance; germination takes place during the rains soon after the seeds fall.

Species 1. *A. hirsuta*, Lam.; 2. *A. integrifolia*, Linn.; 3. *A. Chaplasha*, Roxb.; 4. *A. incisa*, Linn. f.; 5. *A. Lakoocha*, Roxb.

1. *Artocarpus hirsuta*, Lam. Vern. *Ranphannas*, *patphannas*, Mar.; *Heb halasu*, Kan.; *Anjili*, Tam.; *Aini*, Coorg.

A very tall handsome evergreen tree, attaining a height of 150 ft. and a girth of 15 ft. or more, with a straight clean stem and dense foliage. Leaves broadly ovate or elliptical, entire in mature trees, deeply lobed in young plants and coppice-shoots. Wood moderately hard, yellowish brown, durable, of very good quality, much used for house- and boat-building, furniture, and other purposes.

DISTRIBUTION AND HABITAT. Evergreen forests of the Western Ghats from the Konkan southwards, ascending to 4,000 ft. It is not commonly found in the deciduous forests, but where found it appears to grow well, and its scarcity may be due to fires. It is fairly common in the forests of North Kanara, the *ghat* forests of Mysore and Coorg, and southwards through South Canara and Malabar to Travancore, where it is considered one of the most important timber trees of that state. It is often planted in the moister parts of southern India. It requires heavy rainfall, probably not less than 70 in.; otherwise it appears to thrive equally well on the laterite soils at the foot of the *ghats*, on the decomposed gneiss of the slopes, and on rich soils.

FLOWERING AND FRUITING. The yellowish green flower-heads appear from December to March, and the fruit ripens in May-June. The fruit is yellow, ovoid, about the size of a lemon, covered with spines, and containing numerous white seeds, 0.5–0.75 in. long (Fig. 323, *a*). The tree seeds freely every year. The seeds quickly lose their vitality; they germinate readily, but are eagerly devoured by monkeys, which often destroy much of the crop.

GERMINATION (Fig. 323, *b-e*). Hypogeous. The radicle emerges from one end of the seed and descends rapidly, the cotyledonary petioles at the same time elongating and enabling the plumule to extricate itself. The fleshy cotyledons remain underground within the testa.

THE SEEDLING (Fig. 323).

Roots: primary root long, moderately thick, terete, tapering, flexuose, orange brown; lateral roots numerous, short to moderately long, fibrous, distributed down main root. *Hypocotyl* less than 0.1 in. long, sometimes hardly distinguishable, subterranean. **Cotyledons:** petiole 0.1–0.15 in. long, thick, fleshy, flattened; lamina 0.4–0.7 in. by 0.25–0.35 in., thick, fleshy, outer surface rounded, inner flat. **Stem** erect, terete, woody, finely tomentose; first

internode (between cotyledons and first pair of opposite leaves) 2–5 in., subsequent internodes 0.5–1.5 in. long. *Leaves* simple, first pair opposite, subsequent leaves alternate. *Petiole* 0.1–0.3 in. long, tomentose. *Lamina* 1–3.5 in.



FIG. 323. *Artocarpus hirsuta*. Seedling $\times \frac{3}{8}$.

a, seed; *b–e*, germination stages; *f–h*, development of seedling during first month; *i*, seedling towards end of first season.

by 0.6–1.8 in., ovate or obovate, acute or acuminate, base acute or rounded, dentate or serrate, scaberulous tomentose, particularly on lower surface, lateral veins 6–11 pairs.

By the end of the first season the seedling ordinarily attains a height of 5–8 in. with 4–8 leaves and a taproot about 8–10 in. long.

The growth of the seedling is somewhat slow. Plants raised from seed sown in 1914 under shade in abandoned cultivation in Coorg reached an average and maximum height of 2 ft. 4 in. and 4 ft. 9 in. respectively by January 1918. Seedlings require a fairly moist soil and protection from the sun, as they are sensitive to drought. They stand a moderate amount of shade.

SILVICULTURAL CHARACTERS. The tree can stand much shade, but thrives best with a fair amount of light ; it does equally well in the open, and appears capable of standing exposure to the sun after the first few years. Fire is very harmful, scorching the larger trees and killing saplings. The young plants are readily browsed by deer, elephants eat the bark and leaves, and monkeys devour the young shoots. The tree coppices and produces root-suckers ; its coppicing power appears to vary.

NATURAL REPRODUCTION. The seeds fall under and around the trees at the beginning of the rainy season and germinate readily, while birds eat the fleshy fruits and help to scatter the seeds. Natural reproduction, however, is often scanty, usually, it is believed, owing to the heavy shade of the forests in which the tree is found, which prevents the development of the seedlings. Possibly clearing round seed-bearers would help matters. Germination is particularly good in the open, but the seedlings if exposed to the sun are liable to die of drought. Reproduction is prevented to some extent by the destruction of seed by monkeys and of seedlings by deer.

ARTIFICIAL REPRODUCTION. The seedlings are difficult to transplant, and direct sowings are therefore recommended. As the seed is perishable, it should be sown as soon as it ripens. In recent years sowings have been carried out in Coorg in *kumris* (shifting cultivation), five or six seeds being sown at each stake, the stakes being spaced 6 ft. by 6 ft. It has been found necessary, however, to shade the plants in the dry season. This species is therefore more useful for raising as an underwood than for planting in the open, and has been employed successfully in Travancore for undersowing teak plantations. Sowings require protection from deer and monkeys. Bourdillon notes that a whole sowing of 8 or 10 acres in Travancore was completely destroyed one year by monkeys before it was realized that watchers were necessary.

RATE OF GROWTH. According to Bourdillon the growth at first is slow, but when the plants are once established it is rapid. Trees measured at Malayattur in Travancore showed an average growth of 30 ft. in height and 15 in. in girth in five years. At ten years old the girth was 33½ in., and at fourteen years old it was 40 in. Yearly measurements of trees in other places showed a diameter increase of about 1 in. per annum, representing an annual girth increment of over 3 in.

2. *Artocarpus integrifolia*, Linn. Jack. Vern. *Kanthal*, *kathal*, *kathar*, Hind. ; *Phannas*, Mar. ; *Halasu*, Kan. ; *Panasa*, Tel. ; *Pilla*, *pilavu*, Tam. ; *Peinnè*, Burm.

A large evergreen tree with a short thick bole and a dense round crown of dark green foliage. Leaves 4-8 in. long, elliptical or obovate, thickly coriaceous, shining above. Bark dark brown, rough with warty excrescences, inside pale pink or yellow streaked with white, exuding when cut a copious milky juice. Heartwood bright yellow, darkening on exposure, used for

furniture, cabinet-work, turnery, brush-backs, &c. A decoction of chips of the wood is used in Burma for dyeing the yellow robes of priests. The chief importance of the tree lies in its fruit, for which it is extensively cultivated.

DISTRIBUTION AND HABITAT. Probably indigenous to the Western Ghats, in moist evergreen forests, ascending to 4,000 ft. Extensively cultivated for its fruits, or as a shade or ornamental tree, throughout tropical India and Burma. It is actually grown as far north as Dehra Dun and Lahore, but does not thrive. For its best growth it requires a moist tropical climate and a deep rich soil, but is capable of growing on almost any soil. Mr. A. J. W. Milroy¹ has an interesting note on the prevalence of jack trees in the hills of the Abor country bordering on Assam. 'In any report on the jums (shifting cultivation)', he says, 'mention should be made of the striking feature of the Abor hills, the jack tree. Every Abor village is, as a rule, buried in jack trees, but in addition they plant hill slopes, where the soil happens to be particularly stony and shallow, and unsuited for cropping. It so happened that, on one or two occasions, I was disappointed to find that hill-sides, which from a distance of two or three days' march had held out promise of being silviculturally interesting, were merely orchards of jack fruit. These were literally well-stocked forests of jack trees, containing trees of all ages from old and gnarled veterans down to seedlings a year old. The younger trees are protected from the mithun (*Bos frontalis*) by tree guards made of bamboo. On the jums, where crops are grown, there are not as a rule many jack trees. The Abors have no doubt found they thrive sufficiently well on land unsuited for field crops, and so they are only planted on the more unpromising hill-sides, after the tree jungle has been felled.'

The tree is sometimes met with in forest tracts outside the Western Ghats, but in such places it has probably either run wild or marks the site of an abandoned village or former cultivation.

FLOWERING AND FRUITING. The numerous yellowish green flowers, the males on cylindrical receptacles 2-6 in. long and the females on ovoid oblong receptacles, appear from December to March. The large yellowish green ovoid oblong fruits, reaching 1-1.5 ft. or more in length, with a tubercled surface, borne on short stalks on the stem and larger branches, ripen during the rainy season. The fruits contain a number of pale brown, smooth ovoid or reniform seeds, 1-1.5 in. long, surrounded by a yellow pulp (Fig. 324, *a*). The seeds are oily, and have a thin testa; they quickly lose their vitality. Both the pulp and the seeds are eaten, the latter as a rule cooked. The fruits are readily eaten by elephants.

GERMINATION (Fig. 324, *b-d*). Hypogeous. The radicle emerges first. The thick fleshy cotyledons are very unequal; the smaller one separates from the larger like a valve, enabling the young shoot to make its way up from between them. The cotyledons remain underground, supplying the young plant with nutriment for some time before they finally rot off.

This method of hypogeous germination in a large seed with thick fleshy cotyledons is interesting. In many such cases—as in the oaks, *Mesua ferrea*, *Bassia*, *Aesculus*, and even other species of *Artocarpus*—the emergence of the plumule is assisted by the elongation of the cotyledonary stalks and the

¹ Report on the Forest Resources of the Abor Country, 1912.

cotyledons do not separate. In the present case, however, no such elongation takes place, but the emergence of the plumule is effected by the separation of the cotyledons, as is the general rule in epigeous germination ; here the fact that one cotyledon is much smaller than the other, and separates from it like a lid opening, is of special significance in facilitating germination.

THE SEEDLING (Fig. 324).

Roots : primary root long, thick, terete, tapering, pale yellow and delicate when young, afterwards woody ; lateral roots numerous, moderately long, fibrous, distributed down main root, or in germinating stages forming a whorl round its upper part. *Hypocotyl* seldom more than 0.1 in. long, often scarcely distinguishable, subterranean. *Cotyledons* : petiole 0.1–0.3 in. long, broad and flattened, fleshy ; laminae thick, fleshy, unequal, the smaller separating from the larger like a valve ; larger lamina 1.1–1.7 in. by 0.5–0.6 in., ovoid ; smaller lamina 0.8–1 in. by 0.3–0.4 in., elliptical or oblong. *Stem* erect, terete, green, finely pubescent ; internodes 1.2–2.5 in. long. *Leaves* simple, alternate, first few often rudimentary, scale-like and caducous, leaving scars on the stem. Stipules sheathing the terminal bud caducous. Petiole 0.15–0.25 in. long. Lamina 1.5–3.5 in. by 1–2 in., elliptical ovate, acute or acuminate, base rounded or acute, obscurely crenate or entire, coriaceous, dark green, minutely pubescent and scaberulous, lateral veins 6–9 pairs.

The seedling can stand a considerable amount of shade, but develops best in full light, and does not appear to mind the sun provided the soil is kept moist. It is sensitive to drought and very frost-tender. During the first season its growth is slow to moderate, a height of 6 to 18 in. being ordinarily attained by the end of the season.

SILVICULTURAL CHARACTERS. The tree is a pronounced shade-bearer, but develops best with a fair amount of light and growing space ; it is decidedly frost-tender. It coppices well. The bark and leaves are eaten by elephants.

ARTIFICIAL REPRODUCTION. Owing to its long and delicate taproot the seedling does not bear transplanting well, and seed should therefore be sown *in situ* or seedlings should be raised in baskets. The seed should be sown perfectly fresh at the commencement of the rains. Basket plants should be watered regularly in dry weather, and are ready to plant out at the beginning of the rainy season when one year old.

RATE OF GROWTH. The growth is slow at first, but later it is more rapid. Bourdillon says that trees planted at Malayattur in Travancore had a girth of 18½ in. at six years, 29 in. at ten years, and 37 in. at fourteen years.

3. *Artocarpus Chaplasha*, Roxb. Vern. *Chaplash*, *chaplis*, Beng. ; *Lutta*, Nep. ; *Cham*, sam, Ass. ; *Taungpeinnè*, Burm.

A large deciduous tree with a tall straight bole, attaining a height of 100–120 ft. or more and a girth of 10–15 ft. or more, developing a large spreading crown if sufficient room is given. Mature leaves 6–10 in. long, broadly ovate or elliptical, entire, those of young trees and coppice-shoots serrate, lobed or pinnatifid, up to 2 ft. long. Bark smooth, grey with dark blotches in young trees, brown, rough with tubercles and small fissures when old, exfoliating in large rounded flakes, brown inside, exuding a milky juice. Wood yellowish brown, durable, of good quality, used for furniture, building, canoes, boat-building, &c.

DISTRIBUTION AND HABITAT. Sub-Himalayan tract and outer hills from Nepal eastwards, ascending to 5,000 ft., Assam, Chittagong, Burma, and the



FIG. 324. *Artocarpus integrifolia*—SEEDLING $\times \frac{3}{8}$

a—Seed b - d—Germination stages e - g—Development of seedling to end of first season

Andamans. The tree is not gregarious, but is found scattered in moist deciduous and evergreen forests. In Bengal and Assam it occurs scattered in the moist types of mixed deciduous sal and evergreen forests. In Chittagong and Burma it is found in moist tropical forests. In the Andamans it is an important constituent of the evergreen, semi-evergreen, and deciduous forests; in the evergreen forests it is associated with *Dipterocarpus* spp., *Hopea odorata*, *Planchonia andamanica*, *Calophyllum spectabile*, and many others, and in the deciduous forests with *Pterocarpus dalbergioides*, *Albizzia Lebbek*, *Terminalia bialata*, *Lagerstroemia hypoleuca*, &c.

The tree thrives only in moist localities, and is not found in the drier types of forest; the drainage, however, must be good. It is often found along the banks of streams, and prefers a rich deep loam, though it thrives even on clayey soil provided the drainage is good.

In its natural habitat the absolute maximum shade temperature varies from 98° to 105° F., the absolute minimum from 38° to 60° F., and the normal rainfall from 80 to 200 in. or more.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The tree is leafless for a time in the hot season. The globose flower-heads appear in March–April, and the globose tuberculate fleshy fruits, 3–4 in. in diameter, ripen from June to early August. The fruits contain comparatively few seeds; these are oblong, 0.5–0.6 in. long, about 50 weighing 1 oz. (Fig. 325, *a*). The seeds quickly lose their vitality. The fruits are eaten by birds, monkeys, and other animals, as well as human beings, and the seeds are distributed by these agencies.

GERMINATION (Fig. 325, *b–f*). Hypogeous. The yellowish radicle emerges from one end of the seed, and simultaneously the cotyledonary petioles elongate, enabling the plumule to emerge; the young shoot is arched at first, but soon straightens. The fleshy cotyledons remain underground within the testa, and do not separate as in the case of *A. integrifolia*.

THE SEEDLING (Fig. 325).

Roots: primary root long, terete, tapering, flexuose, whitish and delicate in early stages, afterwards woody; lateral roots numerous, fibrous. *Hypocotyl* distinct from and thicker than root, 0.1 in. long, subterranean. *Cotyledons:* petiole 0.2 in. long, broad, flattened, somewhat fleshy, bent to one side of stem; lamina 0.5–0.6 in. by 0.3–0.35 in., thick, fleshy, elliptical, outer surface rounded, inner flat. *Stem* erect, terete or slightly compressed, green, tomentose. *Leaves* simple, first pair usually opposite, subsequent leaves alternate. *Stipules* 0.1 in. long, triangular acuminate, tomentose. *Petiole* 0.1 in. long, tomentose. *Lamina* 1–2.5 in. by 0.6–1.5 in., elliptical or ovate, dentate or serrate, tomentose.

The development of the seedling during the first season is somewhat slow, a height of a few inches being ordinarily attained. The seedling is sensitive to drought and frost; in its natural habitat it probably never experiences the latter, though a long dry season may affect it. It stands a fair amount of shade.

SILVICULTURAL CHARACTERS. The tree is shade-bearing in youth, but requires a fair amount of light for its best development. It is not ordinarily subjected to severe fires in the moist types of forest in which it grows, but when fires do take place it suffers considerably. The young plants are browsed by cattle and deer. The tree coppices well.

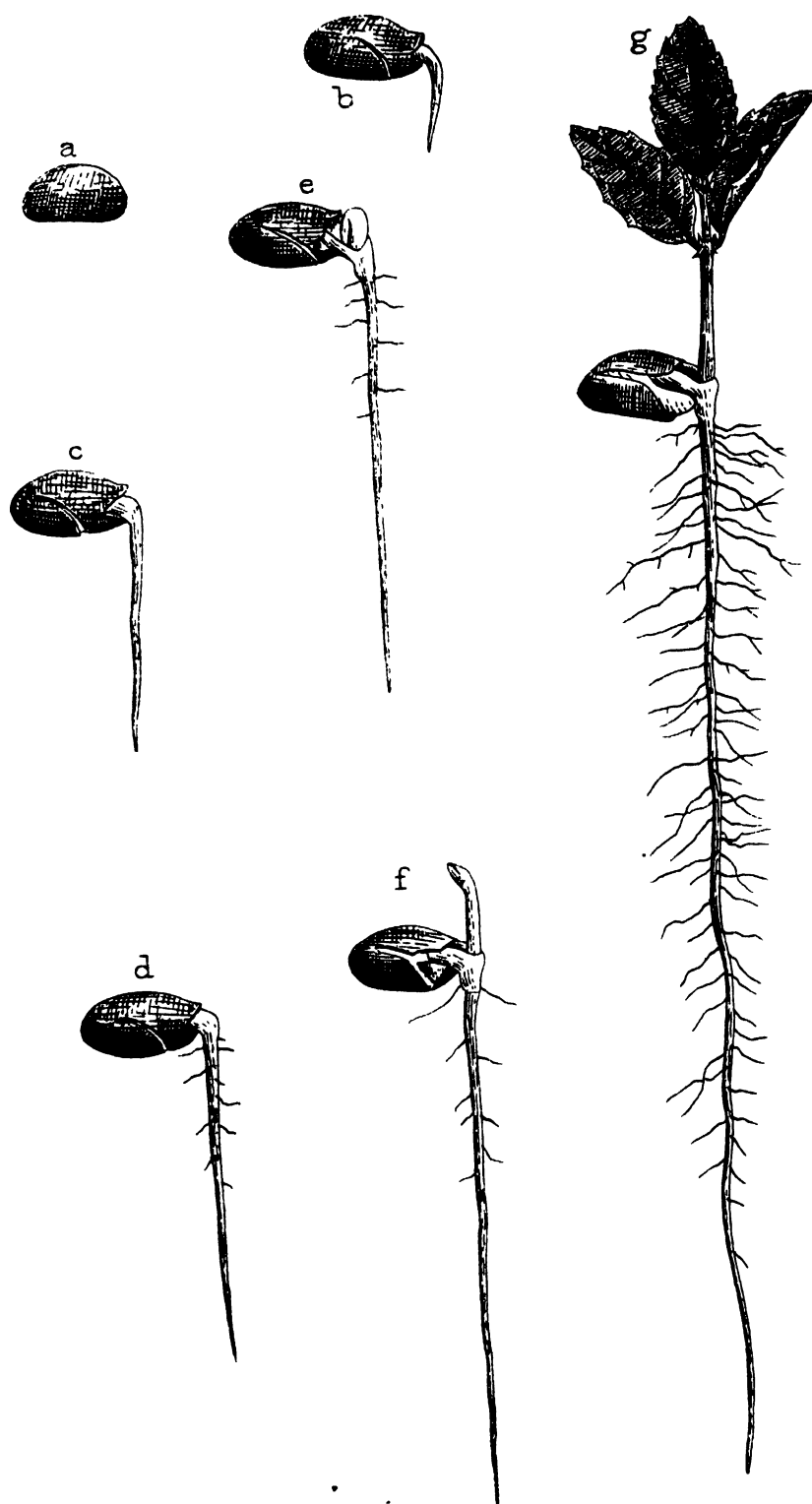


FIG. 325. *Artocarpus Chaplasha*. Seedling $\times \frac{1}{2}$.
 a, seed ; b-f, germination stages ; g, seedling in first season.

NATURAL REPRODUCTION. Large quantities of seed fall to the ground under and around the trees when the fruits ripen early in the rainy season, some fruits falling whole and disintegrating on the ground and others being eaten on the trees by birds and monkeys and the seeds being dropped by them ; a certain amount of seed is also removed by them and dropped at a distance from the trees. Germination commences soon after the seed falls, and takes place readily even if the seeds are not buried. Young seedlings may be found in large numbers during and shortly after the rainy season ; the majority of these are killed off chiefly by dense undergrowth and heavy shade, but where sufficient light is obtained the young plants have little difficulty in making their way up, and in favourable localities natural reproduction is usually good.

ARTIFICIAL REPRODUCTION. The long delicate taproot renders the transplanting of seedlings difficult, and the most satisfactory method of raising young plants is to sow the seeds in long baskets as soon as they ripen and to plant out the seedlings in the baskets, when one year old, at the beginning of the following rainy season. Sowings *in situ* have not been tried. This species would probably prove a suitable one for underplanting or undersowing teak plantations which have been thinned out to afford sufficient light.

4. *Artocarpus incisa*, Linn. f. Breadfruit.

A native of the South Sea islands, cultivated for the sake of its fruit in most tropical countries, including the west coast of India and Burma. The leaves are deeply pinnatifid, up to 3 ft. in length. The tree requires a moist warm tropical climate, and does not thrive far from the sea. It is usually propagated either by carefully digging up and transplanting root-suckers, which are freely produced, or by planting sections of the surface roots about 1 to 2 in. in diameter and about 1½ ft. long. These sections are enclosed in a thick coating of fresh cowdung and clay and buried slightly in a shady bed, which is kept moist. This is done early in the cold season, about October. After the shoots have sprouted they are dug round and manured ; they are finally transplanted at the commencement of the following rains.

For the first few years the plants grow best under slight shade, such as is afforded by partially cleared forest land. Later they require more light for their proper development, and the shade trees should be removed gradually.

5. *Artocarpus Lakoocha*, Roxb. Monkey jack. Vern. *Dheú*, *barhál*, *lakúch*, Hind. ; *Dehua*, Beng. ; *Wotomba*, *badhar*, Mar. ; *Wontemara*, Kan. ; *Naka-renu*, Tel. ; *Myauklók*, Burm.

A large deciduous tree with a spreading crown and large elliptical or ovate entire leaves up to 1 ft. long, softly tomentose beneath. Bark reddish brown, rough and scaly in old trees. Heartwood yellow turning brown, used for building, furniture, canoes, &c. The fruit is eaten, though it is somewhat insipid.

DISTRIBUTION AND HABITAT. The sub-Himalayan tract and outer hills from Kumaun eastwards, ascending to 4,000 ft., Assam, Burma ; Chota Nagpur, truly wild in the Saranda hills, Singbhum (Haines) ; Western Ghats from the Konkan southwards, Andamans. Much cultivated throughout the greater part of India and Burma as a shade or ornamental tree or for the sake of its fruit.

In its wild state it is found chiefly in moist or tropical forests, both deciduous and evergreen, often occurring along the banks of streams and along the sides of moist ravines. In its natural habitat the absolute maximum shade temperature varies from 95° to 115° F., the absolute minimum from 35° to 60° F., and the normal rainfall from 60 to 200 inches. It is, however, cultivated and grows well in northern India in places where greater extremes of temperature are experienced and where the rainfall is less than 60 in.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The tree is leafless or nearly so for a short time in the beginning of the hot season. In northern India the leaves fall during February–March, the new leaves appearing early in April, often before the old ones have all fallen. The flower-heads appear on the leafless branchlets in March–April, and the yellow, somewhat fleshy male heads, often partly eaten by birds, fall to the ground for some weeks after their first appearance. The fruiting period appears to be somewhat irregular. At Dehra Dun the fruits ripen chiefly in July–August, but some, probably a second crop, do not ripen till November. In Chota Nagpur the fruits ripen in May and again in October–November (Haines). The fruits (Fig. 326, *a*) are about 3–4 in. in diameter, irregularly lobed, soft, with a greyish velvety covering, containing an orange somewhat acid pulp, in which the seeds are embedded. The seeds (Fig. 326, *b*) are 0.4–0.5 in. long, white, oblong, rounded. About 65 to 85 weigh 1 oz. The seeds quickly lose their vitality. Fresh seed sown in nursery beds at Dehra Dun showed 81 per cent. of success.

The fruits are greedily eaten by monkeys and by parrots, minahs, and other birds. Throughout the fruiting season the trees are full of birds eating the pulp of the fruits and scattering the white seeds on the ground. The fragments of fruit pulp lying on the ground give out a strong fermenting odour.

GERMINATION (Fig. 326, *c–f*). Hypogeous. The bright yellow radicle emerges from one end of the seed, and simultaneously the cotyledonary petioles elongate, enabling the plumule to extricate itself from between the thick fleshy cotyledons and make its way up. The cotyledons remain underground within the testa, supplying the young plant with nutriment until they finally rot off.

THE SEEDLING (Fig. 326).

Roots: primary root long, thick, terete, tapering, woody, tomentose; lateral roots numerous, fibrous. *Hypocotyl* scarcely distinguishable, very short. *Cotyledons* subterranean; petiole 0.1–0.2 in. long, flattened, fleshy, white, minutely tomentose; lamina 0.4–0.5 in. by 0.35–0.4 in., thick, fleshy, orbicular or broadly elliptical or oblong, outer surface rounded, smooth, inner flat. *Stem* erect, terete, woody, green, tomentose; internodes 0.3–1 in. long. *Leaves* simple, alternate, the first two or three usually abortive and very small. *Stipules* 0.1 in. long; linear lanceolate, tomentose. Petiole 0.1–0.2 in. long, terete, tomentose. Lamina 0.4–2 in. by 0.2–1.2 in., elliptical or ovate, acute or acuminate, base rounded or cordate, irregularly serrate or dentate, dark green, woolly tomentose, venation prominently reticulate, lateral veins 4–8 pairs.

During the first season the growth of the seedling is somewhat slow, a height of 4–8 in. being attained; in the second year the growth is faster, a height of 2 ft. or more being attained under favourable conditions by the



FIG. 326. *Artocarpus Lakoocha*—SEEDLING

a—Fruit $\times \frac{1}{2}$ b—Seed $\times \frac{3}{4}$ c - f—Germination stages $\times \frac{3}{4}$
 g - i—Development of seedling to end of first season $\times \frac{3}{4}$

end of the season. The seedling requires a fair amount of soil moisture, and benefits in the early stages by slight shade. It is sensitive to drought and frost, though it is hardier in this respect than other species of this genus.

SILVICULTURAL CHARACTERS. The tree stands moderate shade in youth, but subsequently develops best with a liberal amount of overhead light. It is the hardiest of the Indian species of *Artocarpus*, but is somewhat frost-tender in the Punjab.

NATURAL REPRODUCTION. The seed, scattered round the trees in the manner already described, germinates during the rainy season, and after the end of the rains numerous seedlings may be found on the ground. Many of these perish during the ensuing dry season, but those which have germinated in a moist and fairly shady situation may survive. Seed lying on the surface of the ground in the open exposed to the sun usually fails to germinate; it is an advantage, therefore, for the seed to become buried before germination takes place. This fact has been verified in the case of seed which has fallen naturally round trees, as well as by definite experiments carried out at Dehra Dun.

ARTIFICIAL REPRODUCTION. There is little difficulty in raising seedlings in the nursery provided perfectly fresh seed is used. The seeds should be sown about 3 in. apart in drills 9 in. apart and covered with earth to a depth of about $\frac{1}{2}$ in. The seedlings should be watered during dry weather, and will be ready for transplanting at the commencement of the following rainy season. Transplanting requires some care owing to the length of the taproot, though the young plants are not quite so sensitive to transplanting as those of other species of *Artocarpus*. The most successful method is to raise seedlings in baskets, to which they may be transferred from seed-beds when about 2 in. high, during the first rains, and to transplant them with the baskets early in the following rainy season.

RATE OF GROWTH. According to Gamble the rate of growth is three to four rings per inch of radius, giving a mean annual girth increment of 1.57 to 2.1 in., which is fast.

3. MORUS, Linn.

Six species of mulberry, possibly not all distinct, are cultivated in the Indian region; three of these, *M. indica*, Linn., *M. serrata*, Roxb., and *M. laevigata*, Wall., are indigenous. The mulberries contain some interesting features, notably their great power of reproduction from cuttings and, in the case of *M. alba* at all events, the striking manner in which natural reproduction takes place, under favourable conditions, from seed spread by water and by birds.

Species 1. *M. alba*, Linn.; 2. *M. indica*, Linn.; 3. *M. serrata*, Roxb.; 4. *M. laevigata*, Wall.

1. *Morus alba*, Linn. White mulberry. Vern. *Tūt, tutri*, Hind.

A moderate-sized deciduous tree with shortly acuminate ovate, often lobed leaves and white or red fruits. The leaves are very variable, and there are many distinct varieties of the tree cultivated or run wild in different countries.

This is the chief mulberry used for silkworm rearing in the Punjab and

Kashmir ; it is also grown for the sake of its fruit, which in cultivated varieties is sweet and succulent. It is grown as a roadside and avenue tree, but is not altogether satisfactory, as it does not live long and soon becomes ragged in the crown and unsightly. The wood is yellowish brown, of good quality, and is used for boats, furniture, turnery, hockey sticks, and other sporting requisites, and to some extent for buggy shafts.

DISTRIBUTION, HABITAT, AND SILVICULTURAL CHARACTERS. Cultivated in Europe, western and central Asia, China and Japan. Frequently cultivated in Baluchistan, Afghanistan, and Kashmir, and in northern India from the plains up to a considerable elevation in the Himalaya. It has run wild extensively in irrigated tracts on the Punjab plains. Henry¹ says that the tree is undoubtedly a native of China, where it is common in the wild state in the mountainous districts of the northern and central provinces, and that its cultivation and the rearing of silkworms can be traced back to the remotest days of Chinese civilization. Mayr² says it grows wild and attains a large size in the forests of central Yezo in Japan.

This is the mulberry which has become so invasive in the irrigated and riverain plantations of *Dalbergia Sissoo* in the Punjab plains (Vol. I, pp. 309, 311). In the early days of the Changa Manga plantation it was planted experimentally on a small scale, and since then has spread to a remarkable extent, and now constitutes probably about 80 per cent. of the growing stock. But for special cleaning operations to protect the sissoo, which is the principal species, the mulberry would doubtless quickly exterminate the sissoo. The plantation is worked as coppice-with-standards. Experiments in cutting back the mulberry to favour the sissoo in young coupes have shown that the crop has to be cut back as a rule at least five times in the first 2½ years before the sissoo is safe from the mulberry. The latter produces seed at an early age, coppice-shoots four or five years old yielding quantities of fertile seed. The mulberry is more shade-bearing and faster growing in youth than the sissoo, coppicing with great vigour and often attaining a height of 15 ft. or more in the first two years ; it has therefore a decided advantage over the sissoo in the struggle for supremacy.

In the Changa Manga plantation the mulberry was at one time regarded as a dangerous weed, but it is now looked on as an important adjunct to the sissoo. Its wood is of somewhat less value, but its growth is faster and its outturn greater, while its shade-bearing character enables it to occupy ground which would otherwise be wasted ; it is a useful soil-protector, promotes straighter and cleaner growth in the sissoo, and materially increases the outturn of the plantation. Moreover the sissoo has for some time been seriously threatened by the fungus *Fomes lucidus*, which has killed the trees off in large numbers for some years past. An accessory species like the mulberry is therefore of great importance. So far the mulberry has been remarkably free from disease in Changa Manga. It is certainly attacked by *Fomes lucidus*, but the fungus appears to be purely saprophytic on it.

Fomes australis, Fr., is a fungus with grey sporophores fairly common on the mulberry in Changa Manga ; it appears to be only a wound parasite not

¹ Elwes and Henry, *The Trees of Great Britain and Ireland*, vi. 1611.

² *Fremdländische Wald- und Parkbäume für Europa*, 1906, p. 485.



FIG 327. *Morus alba*. irrigated plantation, 6 years old, thinned to a density of 1,200 stems per acre, Changa Manga, Punjab.

requiring special control measures at present. Dr. Butler¹ has published an account of the diseases to which this tree is subject.

Experience in Changa Manga has shown that the mulberry does best with a certain amount of shade or protection; it is liable to be broken by wind when grown as pure coppice, and if suddenly exposed as a standard it also suffers from the sun. The mulberry, indeed, has not proved satisfactory as a standard; it is short-lived, growing rapidly but soon becoming hollow, while trees left as standards, if they are not thrown by wind, tend to become branchy, and thus to interfere with the growth of the coppice. Experiments have accordingly been in progress to endeavour to find other suitable species to mix with the sissoo and mulberry, as it is not considered entirely safe to rely on these two species alone. The mulberry, it may be added, is ordinarily frost-hardy, but in Changa Manga it was affected to some extent during the abnormal frost of 1905. It is very liable to be thrown by wind in the Changa Manga plantation, owing largely to the dense state of the crop; trees become so drawn up that they are unable to stand without the support of their neighbours, and when wind gets in extensive windfall results. It is hoped by periodic thinning to counteract this. Fig. 327 shows a mulberry crop in the Changa Manga plantation thinned to a density of 1,200 stems per acre.

NATURAL REPRODUCTION. The spread of the mulberry in the Changa Manga plantation is probably attributable mainly to water, though the seed is also scattered to a considerable extent by starlings (*Pastor roseus*). These birds visit the plantation in large numbers from the end of March to the end of April, when the fruits are ripe, and devour them, scattering the seeds, particularly in newly felled coupes, since the birds prefer the isolated standards as roosting-places. The seed is probably also spread to a small extent by jackals and by human beings. The distribution of the seed by water is demonstrated by the fact that seedlings are often found in abundance along the sides of the irrigation channels, while it has been noticed that in recently started irrigated plantations mulberry has made its appearance in some cases within three years under circumstances which leave no doubt that the seed was water-borne. Further evidence to show that the mulberry seed is freely distributed by water is to be found in riverain plantations. Thus in the Shadara plantation, situated on the low bank of the Ravi river and originally formed of pure sissoo, mulberry has appeared for many years past on the low-lying portions, subject to annual flooding when the river rises, and from there it has spread gradually into the higher parts. The seed has undoubtedly been transported down the Ravi during the flood season, which commences not long after the fruit ripens, from trees growing on the lower slopes of the Himalaya.

ARTIFICIAL PROPAGATION AND TREATMENT. The tree is very easily raised, either from seed or from cuttings. The seed should be sown in June, either *in situ* or in nurseries. In the former case irrigated line sowings are to be recommended if the locality is dry. For transplanting purposes seedlings should be raised in seed-boxes under shade or in well-raised beds shaded from the sun and protected from drip during heavy rain. The fruits should be collected when thoroughly ripe, in April-May, and kneaded in several successive

¹ Mem. Dept. Agric. in India, Bot. Ser., vol. ii, No. 8, April 1909.

washings of water to separate the seeds, and the latter should then be spread out at once to dry in the shade. The seeds and seedlings are subject to insect attacks, and it is therefore sometimes the practice to soak the seeds in water mixed with camphor, and to sprinkle the seed-beds with a mixture of lime, ashes, and a small quantity of white arsenic. The seeds should be sown in June, pricked out about 18 in. apart in the nursery when about 4-6 in. high, and finally transplanted either in the cold season or early in the following rainy season. Before transplanting the lower branches should be pruned off and the upper branches stripped of all but one or two terminal leaves.

For the production of leaves for rearing silkworms the trees will be ready for working in four to five years from the time of transplanting. Meanwhile the stems should be kept free from branches up to 6 or 7 ft. from the ground, by pruning in the cold season. Before the collection of leaves is started the top should be cut off, leaving a total height of 10 to 12 ft., and the branches should be pruned down to promote the formation of pollard-shoots. Pollarding is thereafter carried out regularly, as a rule every second year after the gathering of the winter crop of leaves.

Superior cultivated varieties of mulberry may be budded on to seedlings of the common variety. Budding is carried out towards the end of the cold season on nursery-raised seedlings, one or two years old, cut off at about a foot from ground-level. The Bengal method of raising mulberry from cuttings is described under *M. indica*.

A full account of the methods adopted in Europe for the production of leaves for silk rearing has been published by Maillot and Lambert.¹ The essential operations are careful pruning for the production of pollard-shoots and succulent leaves, and the removal of dead wood and twigs. In France the leaves only are picked, while in Kashmir branches are lopped off, usually without care or system, so that jagged wounds are produced and dead wood is left, resulting in the admission of fungous diseases.²

RATE OF GROWTH AND OUT-TURN. The annual rings in the mulberry are distinct, and ring-countings can therefore be employed for ascertaining the rate of growth. Measurements made in 1913 in the Changa Manga plantation showed the following average rate of growth in girth of dominant coppice-shoots :

Morus alba : girth increment of coppice-shoots, Changa Manga.

Age. years.	Mean girth. in.	Age. years.	Mean girth. in.	Age. years.	Mean girth. in.	Age. years.	Mean girth. in.
1	2.5	7	12.9	13	21.9	19	29.0
2	4.5	8	14.4	14	23.3	20	30.0
3	6.5	9	15.9	15	24.6	21	31.0
4	8.2	10	17.4	16	25.8	22	32.0
5	9.8	11	18.9	17	26.9		
6	11.4	12	20.4	18	28.0		

These figures show a rapid rate of growth for the first six years, after which the growth is somewhat slower.

The following yield table for mulberry coppice in Changa Manga, based on numerous measurements, has been compiled by Mr. E. A. Greswell :

¹ Maillot et Lambert, *Traité sur le Ver à Soie du Mûrier et sur le Mûrier*, pub. Masson et Cie., Paris.

² Butler, *loc. cit.*

Morus alba : yield table for coppice, Changa Manga plantation.

Age. years.	Height. ft.	Girth at 4½ ft. in.	Dominant trees.		Dominated trees, solid volume per acre. cub. ft.	Total solid volume per acre. cub. ft.	Mean annual increment, solid volume. cub. ft.
			No. of trees per acre.	Solid volume per acre. cub. ft.			
1	5	2.0	760	75	—	75	75
2	10	3.5	710	150	25	175	87
3	15	5.0	660	210	50	260	87
4	19	6.0	610	300	50	350	87
5	24	8.0	560	385	65	450	90
6	28	9.0	510	475	75	550	92
7	32	10.0	450	560	115	675	96
8	35	12.0	400	670	140	810	101
9	37	13.5	340	775	175	950	106
10	40	15.0	285	870	230	1,100	110
11	43	16.5	240	970	255	1,225	111
12	45	17.5	200	1,075	275	1,350	112
13	48	19.0	170	1,200	300	1,500	115
14	50	21.0	150	1,320	330	1,650	118
15	52	23.0	130	1,440	335	1,775	118
16	54	25.5	115	1,600	325	1,925	120
17	56	29.0	95	1,750	300	2,050	121
18	58	32.5	85	1,900	290	2,190	122
19	60	35.5	75	2,020	280	2,300	121
20	62	38.0	70	2,150	280	2,430	121

Factors of conversion from stacked to solid measure: Pieces over 2 in. diameter = .54; brushwood = .12.

These figures, it may be noted, refer to the growth in an irrigated plantation, which is no doubt faster than what might be expected under more normal conditions. Gamble mentions that a tree measured in Changa Manga had a girth of 5 ft. 11 in. at fifteen years of age, which is extremely fast.

2. *Morus indica*, Linn. Indian mulberry. Vern. *Tút, tutri, siah tút*, Hind. ; *Posa*, Burm.

A moderate-sized deciduous tree with caudate acuminate, ovate, often lobed leaves and dark purple fruits. This tree is closely allied to *M. alba*, and is sometimes regarded as a mere variety.

Wild in the sub-Himalayan tract in dry forest from the Sutlej eastwards, ascending to 5,000 ft. (Brandis). Extensively cultivated for rearing silkworms in Bengal, and also in Burma, southern India, and other localities. The wood resembles that of *M. alba*.

ARTIFICIAL PROPAGATION AND TREATMENT. This species may be raised from seed in the manner described for *M. alba*. The fruits ripen in April-May. In Bengal and other localities where this mulberry is grown for the rearing of silkworms it is raised from cuttings and worked on a short coppice rotation with intensive cultivation and manuring. The system varies in detail, but the following, described by N. G. Mukerji in his *Handbook of Sericulture*, is a common system in Bengal :

Mature shoots not thicker than a man's thumb are cut into lengths of about 9 in., and planted in clumps of six or seven, the clumps being 18 to 27 in. apart in lines ; the cuttings, planted a few inches apart in each clump, are inserted slanting at an angle of about 60°, and buried except for about 1-2 in., or in dry soils completely buried. The ground is well dug up and repeatedly ploughed and harrowed for some months prior to the planting of

the cuttings. The planting is carried out either in September–October, after the rains are over, or in January–February; the former is the rule in dry soils, and the latter in moist soils. After the cuttings sprout the ground is hoed up, care being taken not to shake or loosen the cuttings. About two to three months after planting, when the shoots ought to be about 20 to 30 in. high, they are cut down almost to ground-level, and ploughing is then done between the lines. The leaves from this first crop are considered bad for silkworms, and are generally used as cattle fodder. All subsequent crops are used for rearing silkworms. As a rule four crops of leaves are obtained, in November, March, June or July, and August. If irrigation is carried out, two extra crops, in January and May, are obtained. The shoots are cut back to ground-level annually in August or September. Intensive earthing, manuring, and tillage is carried out. The earthing consists of annually spreading in April or May fresh earth dug up from tanks or trenches. At the same time the ground is well manured; a dressing of saltpetre, $1\frac{1}{2}$ maunds (about 125 lb.) per acre, applied after the stems are cut back in August or September, is also considered advantageous. A thorough digging is carried out in January, and ploughing or superficial digging is carried out in May, after manuring, September and November. Weeding is done during the rainy season. From two years after the plantation is formed a regular yield of 300 maunds (about 220 cwt.) of leaves per acre per annum should be obtained, from which 1,200 lb. of cocoons can be reared. In the Malda district yields of twice this amount are said to be not unusual.

Another Bengal method, pursued in the Burdwan district, by which cuttings already forced into sprouting are laid horizontally in the planting holes, is described in Sir George Watt's *Commercial Products of India* (1908), p. 785.

In Kollegal, Madras Presidency, most mulberry growers place two or three cuttings about 9 in. long, flat into holes dug 3 or 4 ft. apart, and cover them completely with earth; the shoots are cut back to ground-level annually about July, after which the ground is ploughed or hoed up and manured.

3. *Morus serrata*, Roxb. Himalayan mulberry. Vern. *Karún*, *kimu*, *himu*, *tút*, W. Him.

A moderate-sized or large deciduous tree with leaves usually cordate, often 3-lobed, thickly grey-tomentose beneath. Bark greyish or reddish brown, rough, with vertical fissures in old trees. Heartwood large, yellow or brown, an excellent wood for furniture or cabinet-work, and used for carving and other purposes. Under favourable conditions the tree reaches fairly large dimensions, a height of 60 to 70 ft. and a girth of 9 to 10 ft. being not uncommon. J. L. Stewart mentions several trees 20 ft. in girth, and one 28 ft. in girth at Barmaor in Chamba.

This is the common mulberry of the Himalaya from Kumaun westwards, both wild and cultivated, at 4,000–9,000 ft., occasionally descending lower. It is frequently cultivated in hill stations, and round villages, where it is lopped for cattle fodder.

The trees are leafless during the winter, the new leaves sprouting from March to May, at which time the greenish catkin-like inflorescences cover the

tree, the male spikes being 1-2 in. long and the female spikes 0.5-1 in. long. The flowers are dioecious. The fruits are purple when ripe, and ripen in June-July, when they are greedily devoured by birds, which spread the seeds.

The tree is easily propagated from seed or from cuttings. Fresh seed should be sown in June or July in well-raised beds or in boxes, the seedlings being pricked out next spring and planted out either in the winter or early in the rainy season. It may be found advantageous to prune the stems down and to trim off some of the roots. Seedlings raised at Dehra Dun attained a height of 8 to 14 ft. by the end of the fifth season; this practically represented four years' growth, as the growth during the first season amounted to 1-3 in. only.

Cuttings should be put down in the nursery during the rainy season and planted out when they have become thoroughly rooted. The tree coppices well, and produces root-suckers.

Gamble gives the rate of growth as usually 8 rings, but sometimes 4 rings per inch of radius, representing mean annual girth increments of 0.78 and 1.57 in. respectively.

4. *Morus laevigata*, Wall. Vern. *Kimbu*, Nep.; *Bola*, Ass.; *Tawpwèsa*, Burm.

A large tree of the outer Himalaya from Kumaun eastwards, ascending to 4,000 ft., Assam, Upper Burma (Shan hills), Martaban and Tenasserim (evergreen forests of Thaungyin, Brandis). Sometimes cultivated. In the eastern Himalaya the tree reaches a height of 100 ft. or more, with a girth of 15 ft. (Gamble). The wood is yellowish brown, very handsome, and is used for building, furniture, &c. In Assam it is much used for oars. The fruit, which ripens late in May or during June, is long cylindrical, rather dry, pale yellow when ripe. In the Duars it has been found that the seed is not always fertile; it is possible that such seed may have been collected from dioecious female trees which have not been fertilized.

The growth, according to Gamble, is moderate, averaging 7 rings per inch of radius, which gives a mean annual girth increment of 0.9 in.

4. BROUSSONETIA, Vent.

Broussonetia papyrifera, Vent. Paper mulberry. Vern. *Malaing*, Burm.

A moderate-sized to large tree with somewhat variable mulberry-like leaves and smooth grey bark. Wood sort. The bast fibre is used for paper-making in Japan, Siam, and Burma; in Burma it is made into cardboard blackened for use as slates for writing purposes in schools. The tree attains fairly large dimensions; one over 7 ft. in girth was recently felled at Dehra Dun. Brandis says it is wild in the valley of the Maytharauk, Solo, and other tributaries of the Salween river south of the Karenni country. It is often cultivated, and although it thrives in tropical climates it is also hardy in Europe.

It has become established in some of the irrigated parts of the Punjab, where it has spread from seed and root-suckers. It was introduced many years ago into the Kaunli garden near Dehra Dun, and from there it has spread through the surrounding country. In the garden itself it has become a troublesome weed, spreading not only by seed (probably through the agency of birds),

but also by means of root-suckers, which it sends up in great profusion from its superficial roots. It coppices vigorously. When once it takes possession of an area it is very difficult to eradicate, since if felled and uprooted it maintains its existence by means of the numerous suckers which spring from portions of roots left in the ground. It requires good moist soil to thrive in, and has not succeeded where tried on poor ground or where there is a heavy growth of grass. It is a brittle tree, the branches being easily broken by wind. The fruit, a reddish globose compound fruit in which the achenes hang on long fleshy stalks, ripens in the rainy season (Dehra Dun). The seeds are small and light.

The growth is extremely fast, and in the Kaunli garden this tree quickly outgrows other species. Gamble mentions a specimen from Kaunli averaging 4 rings per inch of radius, and one from Calcutta with one ring per inch of radius, giving mean annual girth increments of 1.57 and 6.28 in. respectively. A cross-section from Kaunli in the silvicultural museum at Dehra Dun showed 25 rings for a girth of 7 ft. 8 in., giving a mean annual girth increment of 3.7 in. Parker states that in Lahore it reaches a height of 60 ft. and a girth of 2-3 ft. in seven years.

The cultivation of this tree in suitable localities in India has been suggested for the purpose of paper manufacture. In Japan it is said to be grown from cuttings and worked on a short coppice rotation of about three years. The shoots are cut into short lengths and steamed, the bark being then stripped off and the outer dark portion scraped off for the coarser qualities of paper, and the inner and finer parts washed, kneaded, bleached in the sun, and then boiled in a lye and pounded into pulp. Mr. W. Raitt, cellulose expert, examined a sample of young coppice bark from Kaunli garden, but doubted if the material could be used for paper manufacture on a large scale unless some cheap process of getting rid of the outer bark could be evolved. Owing to the extremely rapid growth of the coppice-shoots and the high yield which may be expected, this question is worth pursuing farther.

5. CASTILLOA, Cerv.

Castilloa elastica, Cerv. Panama or Central American rubber.

This important rubber tree is indigenous to Mexico from N. lat. 21° southwards, through Central America, and probably also in the north-western portion of South America. In its native home it is a large tree, attaining a height of 180 ft. and a girth of 15 ft., and its growth is very rapid. It was introduced into the East in 1876, since when it has been cultivated to a certain extent in suitable localities in Ceylon and southern India. It has not, however, attained the importance which the Pará rubber has done; not only does it give lower yields than the latter, but ordinarily it cannot be safely tapped under seven years of age, as against four or five years for Pará rubber.

The tree prefers a warm steamy climate and an elevation not much above sea-level, though it occasionally ascends to 1,500 ft. on the Pacific coast. It thrives best with a rainfall of 80 to 120 in. and an equable temperature averaging 77° to 85° F., and never falling below 60° F. It is exacting as to soil, requiring a deep fertile loam and avoiding marshy ground; it is found most commonly along the banks of streams.

The leaves are large and oblong, and the fruit is a fleshy receptacle containing numerous seeds about $\frac{1}{4}$ in. in diameter. The seeds do not retain their germinative power long. The tree may be raised from seed or from cuttings; the latter, it is said, should be taken from the main shoots and not from the branches, as cuttings from these tend to grow more or less horizontally.

ORDER LV. PLATANACEAE

PLATANUS, Linn.

Platanus orientalis, Linn. Plane, eastern plane. Vern. *Chinar*, Pers., Hind. ; *Buna*, *buin*, *bhunj*, Kashm.

A large deciduous tree with alternate palmi-nerved 5- to 7-lobed, rarely 3-lobed leaves, the bases of the petioles enclosing and concealing the buds. Bark smooth, thin, light grey or greenish, exfoliating in large thin scales, exposing the light yellow new bark in patches; bark at the base of old trees dark, thick, and furrowed. Wood yellowish or reddish white, used in Kashmir for boxes and small fancy lacquered articles; a good fuel.

The tree is indigenous to the eastern Mediterranean region, and is cultivated in Afghanistan, Baluchistan, and the western Himalaya from 2,000 to over 8,000 ft., particularly in the Kashmir valley. It grows fairly well in the Punjab plains if well supplied with moisture. It has been tried without success at Maymyo in Burma. Under favourable conditions it attains very large dimensions. Mr. J. C. McDonnell¹ records the girths of two large trees in Kashmir, (1) at Drogmula, 50 ft. girth, (2) at Jahama, 43 ft. girth (hollow). Mr. A. E. Wild² records a tree 36 ft. in girth measured in 1890 at Nilan Bhoto, Hazara. In 1918 I measured the same tree and found it to be 37 ft. 7 in. in girth; it was a spreading tree branching from near the base. The largest girth noted by Dr. Stewart at Srinagar was 28 ft. The tree grows best on moist deep well-drained soil. In Greece it grows wild along torrents in the mountainous districts. In the western Himalaya the leaves fall about October–November, and the new leaves appear in April. The flowers, which are monoecious in unisexual globose heads, appear in April–May, and the fruit ripens in June–July, remaining long on the tree. The seeds are very small and light, and for growing seedlings it is advisable to have well-raised seed-beds of finely pulverized soil containing a considerable percentage of sand; the seed should then be mixed with sand, loam, and water, and spread evenly over the surface of the beds. Careful watering is necessary, either by percolation or with a very fine spray, or the beds may be covered with straw and watered until germination commences. The seedlings grow slowly at first, and it is preferable not to plant them out until they are at least two years old. The plants can be transplanted without difficulty even when of a fair size. The tree can be raised successfully from layers and cuttings, even large thick stakes rooting successfully. It has been found that the best method of preparing cuttings is to tear off twigs about 1 ft. long so that a strip of the older branch to which they are attached remains at their base; the cuttings should then be planted several inches deep.

¹ Ind. Forester, xxix (1903), p. 152.

² *Ibid.*, xxiii (1897), p. 206.

Elwes¹ states that in England the tree is always liable to be cut by frost at any age, and the branches and twigs assume a zigzag habit in consequence; when of sufficient size it seems able to endure the severest winter frosts, but requires a fairly high summer temperature. He adds that it should not be planted on poor, stony land or in places exposed to cold winds, and that it is one of the few trees that will grow on strongly alkaline soil, and has been successfully planted on the alkaline lands of the San Joaquin valley in California.² In India it is quite frost-hardy.

The rate of growth is fairly fast. A specimen from Hazara, examined by Gamble, showed 6 rings per inch of radius, giving a mean annual girth increment of 1.05 in. Brandis mentions that the Nasim Bagh on the border of the great Kashmir lake is a large grove of plane trees planted by Akbar the Great soon after he had taken Kashmir in 1586. In 1838 Vigne found the average girth to be 13 ft., and supposed their age to be 248 years. The largest, close to the water, averaged 20 ft. in girth. Of two trees 170 years old at Brein in Kashmir Vigne found one 16 ft. 2 in., the other 20 ft. 10 in. in girth.

Var. *acerifolia*, Aiton (*P. acerifolia*, Willd.), is the London plane, so commonly planted in the squares and parks of London, and remarkable for its capacity for standing the smoky air of towns. The leaves are often 3-lobed. It has recently been tried in Baluchistan, but in March 1916 it suffered from late frost, having sprouted early owing to a mild winter.

ORDER LVI. JUGLANDACEAE

Genera 1. JUGLANS, Linn.; 2. ENGELHARDTIA, Lesch.

1. JUGLANS, Linn.

Juglans regia, Linn. Walnut. Vern. *Akhor*, *khori*, *krot*, *akhrot*, *dún*, W. Him.; *Thitcha*, Burm.

A large deciduous tree with imparipinnate leaves up to 15 in. long, fragrant when crushed, with 5 to 9, sometimes up to 13, leaflets. Twigs with chambered pith. Bark of young trees light grey, with vertical striations; that of older trees light or dark grey, with deep vertical parallel fissures. Wood even-grained, greyish brown with dark brown streaks, often beautifully mottled, used for furniture, cabinet-making, carving, and gunstocks. The burrs are particularly valuable, and are used for veneer; they have been extensively worked in the past in the forests of Kashmir, and within recent years have been exploited in Hazara. As a fruit-tree the walnut is well known.

When grown as a fruit-tree in the open it has a spreading crown and a comparatively short bole, but in the forest it is often a tall tree with a long clean stem, attaining a total height of 80–100 ft. or even more, with a girth of 10–15 ft. or more. Brandis mentions a tree of 22 ft. girth at Sali on the Chenab (8,200 ft.), and Stewart one of 28 ft. in Kulu. Mr. J. C. McDonnell³ records two large trees in Kashmir, (1) girth 20 ft. 10 in. at Salkut, (2) 20 ft. 2 in. at Sogam.

¹ Elwes and Henry, *The Trees of Great Britain and Ireland*, iii. 621.

² Hilyard, *Soils* (1906), p. 480.

³ Ind. Forester, xxix (1903), p. 152.



FIG. 328. *Juglans regia* in forest of silver fir (*Abies Pindrow*), Hazara.



FIG. 329. Typical area of pure walnut (*Juglans regia*), Kagan valley, Hazara.



FIG. 330. Pure pole crop of walnut (*Juglans regia*), showing straight clean stems owing to dense growth Hazara.

The burrs sometimes attain a large size. In 1918 I measured one in the upper Siran valley, Hazara, which was 25 ft. in circumference and $2\frac{1}{2}$ ft. thick; the girth of the tree above the burr, which was near its base, was 14 ft. 3 in.

There are numerous cultivated varieties of nut, the one most prized being the *kaghazi* (paper shelled) walnut of Kashmir, a large nut with a shell so thin as to be easily breakable between the finger and thumb of one hand.

DISTRIBUTION AND HABITAT. The walnut has a wide natural range, occurring wild in Greece, the Balkans, through Asia Minor, the Caucasus, Persia, Afghanistan, the Himalaya, the hills of Upper Burma, and possibly in north China and Japan. It is extensively cultivated in France and in southern Europe generally, also in the Himalaya and in China and Japan.

In the Himalaya it is indigenous usually at 4,500 to 11,000 ft., extending west to Afghanistan and east to Bhutan. In the west it grows either in pure groups or in mixture with other broad-leaved species such as maples, oaks, horse-chestnut, and bird-cherry, or with conifers, particularly spruce, silver fir, blue pine, and yew. It occurs chiefly on deep well-drained fertile soil, often containing boulders, in sheltered situations such as moist ravines or depressions on the hill-sides. It avoids stiff badly drained soil. When mixed with conifers it is commonest and grows best in fairly moist localities, often in association with silver fir (see Fig. 328); but it occurs sometimes mixed with blue pine on rather dry slopes on hot aspects, though here it is somewhat stunted. Pure crops of walnut are often found on the lower gentle slopes of well-drained cup-like depressions the upper parts of which are occupied by coniferous forest. It is a characteristic tree on the higher grazing grounds of Hazara, where it occurs often in pure groups.

The walnut is more abundant in Kashmir and Hazara than it is farther east, where, though common locally, it is not so widely distributed. In Hazara it is particularly common in the Kagan valley, often forming pure crops of considerable extent on the gentle slopes of basin-like ravines. Fig. 329 shows a typical pure crop in this locality, and Fig. 330 shows a pure pole crop in the upper Siran valley in Hazara.

In the eastern Himalaya it is found mixed with oaks, maples, laurels, magnolias, and other trees; natural trees, however, are rare in the Darjeeling hills, having been much cut out in former years.

The walnut is extensively cultivated for its fruit throughout the Himalaya and in the Khasi hills. It grows well at Mogôk in Upper Burma, but has not succeeded at Maymyo.

LEAF-SHEDDING, FLOWERING, AND FRUITING. In the Himalaya the walnut is one of the first species to lose its leaves. The leaves fall during September, some trees being almost leafless by the end of that month; others retain their leaves until well on in October, but by the latter half of November the trees are usually all leafless. The new leaves appear in March-April. The flowers appear with the new leaves. The male catkins are green, 2-5 in. long, arising singly or in pairs above the leaf-scars on the previous year's shoots. The female flowers, green with bifid styles, occur singly or up to four together at the apex of the young shoots. The fruits ripen chiefly in September, sometimes as early as July. The fruit is a green drupe, ovoid or nearly globular,

about 2 in. long, with a very aromatic leathery pericarp, which splits irregularly when ripe. The enclosed nut (Fig. 331, *a*) is 2-valved, wrinkled and furrowed on the surface, and variable in size, shape and thickness of shell, usually 1-1.5 in. long : it is divided inside by two thin dissepiments into four incomplete cells, one dissepiment separating the two cotyledons, the other dividing them into two lobes. The wild walnuts have extremely thick, hard shells, and cannot be broken except by hard hammering. In the case of average-sized cultivated walnuts grown in hill villages in the western Himalaya about 45 to 50 were found to weigh 1 lb. ; actually the weight varies greatly with different varieties. Sound nuts have a high percentage of fertility.

In the forest the nuts are very subject to the attacks of monkeys, squirrels, rats, and birds, particularly nutcrackers. Quantities of wild walnuts may be found lying on the ground near the trees, every one with the thick shell bored through on one or both sides by rats. Bears also collect the nuts ; a case was recently recorded from Hazara in which the winter quarters of a black bear were found to be well stored with quantities of walnuts.

GERMINATION (Fig. 331, *b*, *c*). Hypogeous. The nut splits slightly at the suture and the radicle emerges from its basal end. The cotyledonary petioles elongate and the stout taproot attains a considerable length before the young shoot develops. The latter elongates first by arching, soon becoming erect.

THE SEEDLING (Fig. 331).

Roots : primary root long, thick, fleshy, becoming woody ; lateral roots numerous, long, fibrous, distributed down main root. **Hypocotyl** short, thick, not readily distinguishable. **Cotyledons** : petiole up to 0.5 in. long, thick, fleshy ; lamina 0.7-1.2 in. by 0.5-1 in., thick, fleshy, obovate, bilobed, much wrinkled. **Stem** erect, terete or obscurely angular, woody, glabrous, green to greenish brown, covered with lenticels ; internodes 0.4-2.5 in. long. **Leaves** exstipulate, first few scale-like, abortive, normal leaves alternate, imparipinnate, first three or four usually 5-foliate, sometimes 3-foliate, sometimes 6-foliate by division of terminal leaflet, subsequent leaves in first season chiefly 7-foliate, in second season usually 9-foliate, sometimes 7-foliate. Rachis 3-8 in. long, glabrous. Terminal leaflet larger than lateral ones, 3-8 in. by 2-4.5 in., elliptical or obovate, acuminate, irregularly dentate or serrate. Lateral leaflets sub-sessile, 1.5-5 in. by 1-2.5 in., unequally ovate acuminate, basal pair smaller than remainder. The leaves of seedlings, like those of the adult plant, have a characteristic fragrant odour when crushed.

The growth of the seedling is moderately fast. Nursery-raised plants at Dehra Dun reached a height of 1-1½ ft. by the end of the first season, 3-4 ft. by the end of the second season, and 7-8 ft. by the end of the third season. Seedlings raised from direct sowings in the Darjeeling hills attain a height of nearly 1 ft. by the end of the first rains and a height of about 3 ft. by the end of the second rains, and thereafter grow about 2 to 3 ft. annually. At Simla the growth is slower. Seedlings from direct sowings attained a height of only 3-6 in. by the end of the first season, while those raised in good soil in the nursery reached a height of 6-10 in. by the end of the first season, and 1-2 ft., after being planted out, by the end of the second season. Natural seedlings usually attain a height of 1-1½ ft. in three years. The seedling produces a long stout taproot, which may reach a length of 2 ft. and a diameter of 1 in. by the end of the first season. The young plants require a moist but well-drained soil ; they stand slight shade only, but benefit by side protection



FIG. 331. *Juglans regia* SEEDLING $\times \frac{1}{2}$
 a—Fruit stone b-c—Germination stages d—Young seedling

from the sun in dry localities. They respond readily to cultivation, and are hindered by weed-growth. They are somewhat sensitive to drought and frost. In dry situations the seedlings die back from drought in the hot season, but unless severely affected they sprout again from the base. Young plants are much subject to damage from browsing by barking deer where these animals are present.

SILVICULTURAL CHARACTERS. The walnut is a light-demander, though it stands slight shade in youth; in Europe it is usually considered to be similar to the oak (*Quercus Robur*) as regards light requirements. At the same time it requires to be grown in a close crop if straight clean timber is wanted, owing to its marked tendency to produce large spreading branches. The root-system is massive, spreading, largely superficial but also penetrating deep. The tree is wind-firm, though it does not thrive in exposed windy situations and is liable to be broken. Saplings in the Himalaya are liable to be barked by deer rubbing their horns. The bark is also frequently removed by the hill people, and is used for cleaning the teeth, for which purpose it has a commercial value. The walnut coppices well.

NATURAL REPRODUCTION. The fruits fall under and around the trees towards the end of the year, the pericarp cracking and rotting off. The nuts, however, are so subject to the attacks of birds and monkeys on the trees and of rodents on the ground, that large quantities are destroyed; the noticeable scarcity of natural reproduction in the forest is usually attributed, probably rightly, to this fact. Some experiments to ascertain the factors influencing natural reproduction have been carried out at Dehra Dun, but these were not extensive enough to give complete results. So far as they go they indicate that for successful germination a fair degree of warmth combined with soil-moisture is necessary, and the nuts require a covering of earth or débris over them, failing which the radicle dries up and the germinating seedling dies. These conditions are ordinarily fulfilled in moist depressions so situated that they receive the sun's warmth for a part of the day, while the nuts roll into them and become mixed with and covered by earth and débris which is washed into the depressions. In the forest the best natural reproduction is found on moderate to gentle slopes on loose but deep fairly moist soil where boulders and rock fragments are plentiful; the boulders appear to act as a protection to the nuts, which lodge behind them and become quickly covered with débris. Good crops of young walnut are often found on the recent detrital accumulations formed by the weathering of cliffs or the erosion of hill-sides, and on deep loose rubble on landslips in the open.

ARTIFICIAL REPRODUCTION. Cultivated varieties are best propagated by budding or grafting. For forest purposes the tree may be raised either by direct sowings, in which case the nuts should be covered to a depth of about 2 in., or by transplanting nursery-raised plants. The former method has proved the more successful in the Darjeeling hills, and is usually successful in places where the nuts are not liable to be destroyed by vermin, otherwise it is necessary to raise seedlings in the nursery and transplant them. In experiments carried out at Simla transplants from the nursery proved stronger and developed more rapidly than plants obtained by dibbling *in situ*. The chief difficulty connected with transplanting is the fact that the walnut seedling

produces a very long stout taproot. This difficulty can be overcome at the time of transplanting by pruning the stem down to about 1 in. from ground-level and trimming the taproot down to a length of about 9 in. ; transplanting is thereby facilitated. The seedlings stand this treatment well, and shoot up again from the base ; in this case two or more shoots usually appear from one stump, and it is necessary at the end of the season to prune down all but the best shoot. Provided care is taken, however, the transplanting of seedlings during the first winter can be carried out quite successfully without any pruning of the stem and root, or with very slight trimming of the root, and such plants subsequently develop more rapidly than those which have been pruned down.

The nuts should be carefully stored from the time of ripening to the time of sowing, in order to protect them from vermin ; this is best effected by hanging them up in bags or keeping them in covered earthenware jars. In sowing the nuts it is advisable to place them on their sides in order to promote germination in a natural position. In the nursery the nuts should be sown about 2 in. deep in prepared seed-beds of fine rich mould in a warm situation ; the drills should be about 9 in. apart, the nuts being placed 3 to 4 in. apart in the drills. They are commonly sown in January or February, but where the snowfall is heavy they should be sown early in December, before the snow falls. Regular watering is necessary until the rainy season commences, and it is advisable to cover the beds with thorns to keep off vermin until germination is completed. Where rats are feared it is advisable also to fence the nursery with small-mesh wire netting, which should be buried several inches in the ground. The seedlings may be transplanted in the following cold season, after rain, the taproot being slightly trimmed if necessary and the planting holes being filled with rich soil. If larger plants are required the seedlings should be pricked out during the first winter with a spacing of about 1 ft. by 1½ ft., the taproots being trimmed, and finally transplanted during the second winter. Transplanting during the rains has proved fairly successful at Simla, but not so successful as winter planting.

Walnut requires to be planted somewhat closely in order to prevent branching. On gentle slopes or level ground a spacing of 6 ft. by 6 ft. is suitable, while on steeper slopes perhaps the best spacing would be 5 ft. apart in contour lines 8 or 9 ft. apart measured on the slope.

Dibblings *in situ* have been carried out with success in the Darjeeling hills. These dibblings are carried out in small groups to fill up blanks in the forest. The best situation is a damp depression ; the sites of old charcoal kilns, which are usually in depressions, have given particularly good results, the mixture of earth and charcoal aiding germination and favouring growth. A spacing of about 6 ft. by 6 ft. is usually adopted. The soil at each stake is loosened to a depth of about 1 ft., and one nut is placed at each stake about 2 or 3 in. deep. The best time for sowing is January or February. Before germination takes place the sowings have to be carefully guarded from boys, who dig up the nuts to eat them ; squirrels have also to be guarded against, and this is effected by placing thorny branches over the places where the nuts are sown. The young plantations have to be fenced against deer.

SILVICULTURAL TREATMENT. In the Himalaya natural reproduction

cannot be relied on to a sufficient extent to employ any systematized treatment relying on reproduction by natural means. The only system which appears to be thoroughly applicable is that of clear-felling with artificial reproduction, and this is the system about to be introduced on a fairly large scale in Hazara. The growth of natural walnut in the western Himalaya indicates that it is well adapted for growing in dense pure even-aged crops, for natural crops answering this description are occasionally to be met with, and the trees produced are tall, straight, and clean boled (see Fig. 330). Although the walnut is often found mixed with conifers its presence under such conditions is not as a rule desirable, since it occupies much space with its spreading branches, and conifers do not come up readily beneath it; this is particularly the case with the blue pine (*Pinus excelsa*). Hence where the main object is to grow conifers it is advisable to cut out all branchy walnut trees from coniferous crops. On the other hand, walnut should be grown in separate crops by itself on favourable ground such as moist well-drained slopes and the sides of ravines at suitable elevations.

STATISTICAL. (1) *Bark thickness.* A limited number of measurements made in the Kagan valley, Hazara, gave the following average bark thickness for trees of different sizes :

Juglans regia : bark thickness, Kagan valley, Hazara.

Girth.	Average bark thickness.	Girth.	Average bark thickness.
2 ft.-2 ft. 11 in.	0.4 in.	5 ft.-5 ft. 11 in.	1.3 in.
3 ft.-3 ft. 11 in.	0.7 in.	6 ft.-6 ft. 11 in.	1.6 in.
4 ft.-4 ft. 11 in.	1.0 in.	7 ft. and over.	1.8 in.

(2) *Rate of growth.* Ring-countings on six stumps of naturally grown trees in the Kagan valley in 1918 gave the following mean rate of growth :

Juglans regia : rate of growth in girth, Kagan valley, Hazara.

Age.	Mean girth (including bark).	Age.	Mean girth (including bark).	Age.	Mean girth (including bark).
years.	ft. in.	years.	ft. in.	years.	ft. in.
10	0 5	70	3 10	130	6 4
20	0 11	80	4 3	140	6 9
30	1 6	90	4 8	150	7 1
40	2 1	100	5 1	160	7 5
50	2 9	110	5 6	170	7 9
60	3 4	120	5 11	180	8 1

According to Gamble the rate of growth is about 15 rings per inch of radius in the western Himalaya, 6 rings in the Sikkim Himalaya, and $3\frac{1}{4}$ rings for planted trees in the latter region; the corresponding mean annual girth increments are 0.42, 1.05, and 1.92 in. respectively. A cross-section 3 ft. 6 in. in girth from the western Himalaya in the silvicultural museum at Dehra Dun had 87 rings, giving a mean annual girth increment of 0.48 in. Walnut trees planted from 1880 to 1887 on the slopes of China, Naini Tal, commenced bearing about 1905, and in 1909 their average height and girth were 30 ft. and $2\frac{1}{4}$ ft. respectively.

Measurements recorded by Forstmeister Rebmann¹ at Strassburg showed

¹ Allgemeine Forst- und Jagd-Zeitung, August, 1912, p. 257.

that trees eighty years old had an average diameter on poor sand of 16–17 in., on slate of 20–22 in., on better diluvial sand of 22–24 in., and on lime and loam soils of 26–28 in. .

2. ENGELHARDTIA, Lesch.

Engelhardtia spicata, Blume, including *E. Roxburghiana*, Lindl., *E. acerifolia*, Bl., *E. Colebrookiana*, Lindl., and *E. villosa*, Kurz. Vern. *Mowa*, *gadhmowa*, *gobar mowa*, Hind. ; *Taung-tamasók*, *petsut*, *thitsawbwa*, Burm.

A moderate-sized to large deciduous tree with grey bark and leaves usually paripinnate. Wood reddish grey, moderately hard, used for tea-boxes and carving. Common and sometimes almost gregarious in the outer Himalaya up to 6,000 ft., usually on rather dry situations ; also in Assam, Manipur, Chittagong, and Burma, in the Shan hills and the hill *indaing* forests of Martaban and Tenasserim.

The tree is monoecious. In the outer Himalaya the spikes of ripe fruits are visible on the trees in May–June, and by the middle of June many of the fruits, with conspicuous light brown 3-lobed bracts, have fallen to the ground, often conveyed by wind to some distance from the tree. The nuts have irritant hairs.

This tree produces root-suckers in abundance, and is thus useful for binding unstable hill-sides. Gamble says that in some localities it forms a kind of coppice growth, as at Nagri in the Darjeeling hills ; also that natural reproduction is excellent wherever the seedlings get sufficient light and are protected from cattle.

Growth, according to Gamble, 5 to 7 rings per inch of radius, giving a mean annual girth increment of 0.9 to 1.26 in. A cross-section 5 ft. 8 in. in girth in the silvicultural museum at Dehra Dun had 57 rings, giving a mean annual girth increment of 1.2 in.

ORDER LVII. CASUARINACEAE

CASUARINA, Forst.

Casuarina equisetifolia, Forst. *Casuarina*, beefwood (Australia). Vern. *Sura*, Mar. ; *Chowku*, *saruku*, Tel. ; *Cavukku*, Tam. ; *Pinlè-kabwè*, *tinyu* (meaning ' pine '), Burm.

A large evergreen tree with a straight stem and feathery foliage consisting of numerous long, slender, drooping, jointed, 6–8 angled leafless branchlets arising from rough woody branches ; the jointed branchlets, which are partly deciduous, are green, and fulfil the functions of leaves. Bark brown, rough, fibrous, exfoliating in longitudinal strips. Wood very hard, much liable to crack and split ; used sometimes for poles and rafters, but chiefly for fuel, for which purpose it is excellent.

In general appearance the casuarina resembles a feathery conifer. It attains under favourable conditions a height of 100 ft. or more ; trees up to 131 ft. in height have been measured in a plantation forty years old in North Kanara. It is particularly valuable for afforesting sandy beaches and shifting sand-dunes along the sea-coast ; numerous stretches of sand along the Coromandel coast and parts of the west coast have been reclaimed and utilized by

means of plantations of casuarina, under which it is eventually possible to introduce other species. The tree is not a long-lived one, probably seldom surviving more than fifty years even in favourable situations, and in less favourable localities scarcely reaching twenty-five years before becoming hollow and misshapen.

DISTRIBUTION AND HABITAT. Indigenous on sandy shores and dunes along the coast of Chittagong, Tenasserim, and the Andamans, particularly in the Little Andaman; also in the Malay Archipelago, the Malay Peninsula, chiefly on the east coast, the Pacific islands, North Australia, and Queensland. It is cultivated throughout the greater part of India, not only in plantations along the coast, but also inland as an ornamental or avenue tree, and sometimes in plantations. It thrives best in close proximity to the sea on loose sand, growing sometimes to within a few yards of high-tide level, and even with its roots in the sea; inland it tends to become dry topped and unsightly at a comparatively early age. In its natural state it is gregarious, forming pure crops with little or no undergrowth except grass and a few coastal shrubs. Although it thrives on pure loose sand or very sandy loam it has been grown with success on reclaimed mangrove soil in the Malay Peninsula. It is grown as an ornamental tree on various soils in India, but does not thrive on clay, preferring a sandy soil. On badly drained ground subject to inundation the trees become unhealthy and die off; on sandy soils where the water-level sinks too low in the dry season they tend to become stunted and even bush-like. In the natural habitat of the tree on the coasts of Burma, Chittagong, and the Andamans the absolute maximum shade temperature varies from 98° to 101° F., the absolute minimum from 45° to 60° F., and the normal rainfall from 100 to 200 inches. On the coasts of the Indian Peninsula, where it thrives well, the absolute maximum shade temperature varies from 96° to 116° F., the absolute minimum from 45° to 63° F., and the normal rainfall from 35 to 150 inches. Inland it is grown in regions subject to greater extremes of temperature, but its growth, as already stated, is poorer than it is along the sea-coast.

LEAF-SHEDDING, FLOWERING, AND FRUITING. Pieces of the jointed branchlets are shed throughout the year, and in casuarina plantations form a thick layer on the surface of the ground. The tree ordinarily flowers twice a year, from February to April and in September–October, the fruits ripening in June and December. The flowers are unisexual, and are arranged in small spikes. The fruits are globose woody cones, 0.75 in. in diameter, containing a number of winged achenes, each enclosing a solitary seed. The achene (Fig. 332, *a*) is light brown, terminating in a membranous wing, the whole 0.2–0.3 in. long. The achenes are very light, about 20,000 weighing 1 oz. The seeds retain their vitality for a few months, and to some extent for a year; tests at Dehra Dun gave a fertility of 5 per cent. for seed kept one year, but after eighteen months the fertility was nil. It is always desirable to use fresh seed. Trees on the coast commence bearing seed when about four or five years old. The seeds, both on the coast and inland, are very liable to the attacks of ants, which carry them off in large quantities from the nursery-beds.

GERMINATION (Fig. 332, *b-i*). Epigeous. The radicle emerges towards the winged end of the achene. The hypocotyl elongates by pronounced

arching, and in straightening raises the cotyledons above ground, the slender jointed scaly shoot soon appearing from their axil. The shell of the achene is usually carried up over the cotyledons, falling with their expansion.

THE SEEDLING (Fig. 332).

Roots : primary root moderately long, thin, wiry, flexuose ; lateral roots numerous, fine, fibrous. *Hypocotyl* distinct from root, 0.5–0.8 in. long, cylindrical, slender, delicate at first, becoming wiry, yellow or green, turning red, then brown. *Cotyledons* sessile, 0.1 in. long, foliaceous, elliptical, entire, yellow turning green, then dark red. *Stem* erect, slender, entirely covered by the whorls of scale-like leaves, and appearing as if jointed. *Leaves* verticillate, scale-like, in whorls of 6 to 8, 0.1–0.2 in. long, decurrent round the stem except for the small acicular tips and forming ridges, the ridges of each whorl lying opposite the hollows of the next whorl, dark green or reddish green, later turning brown.

In the nurseries of the coastal regions the growth of the seedling is rapid, a height of 18 in. to 2 ft. or more being attained in the first season, with subsequent growth at the rate of 4 to 5 ft. per annum for a few years. Under less favourable conditions the growth is somewhat slower. At Dehra Dun seedlings reached the following heights during the first five seasons : (1) 6–10 in., (2) 3–4½ ft., (3) 8½–10 ft., (4) 11 ft., (5) 12½ ft.

The seedlings are very sensitive to drought and to excessive moisture. Seedlings of a tropical littoral species like *casuarina* might be expected to be frost-tender, but at Dehra Dun this was found not to be the case, the young plants remaining quite uninjured by frost when several indigenous species suffered. The seedlings have many enemies ; hares, squirrels, and rats damage them, and on the coast they are subject to the attacks of crabs, which nip through the stems. They are very liable also to the attacks of crickets and other insects.

SILVICULTURAL CHARACTERS. The tree is a strong light-demander, suffering readily from suppression. Although the seedlings are very sensitive to drought the trees of the coast plantations have proved remarkably drought-resistant, though this may be due to the fact that the subsoil water-level is not far from the surface. In the exposed position in which they stand the trees of the coast plantations are occasionally uprooted, or have their branches broken, by storms, although they appear to stand the force of the monsoon better than most species. The *casuarina* is very susceptible to damage by fire ; the removal of the fallen twigs, a common practice in the coast plantations, considerably lessens the risk of fire, while in some plantations it is found necessary, for protective purposes, to remove grass in the young plantations.

Root-suckers sometimes appear in profusion in coast plantations, but this is not by any means universal ; the trees also reproduce by natural layers from the lower branches. The roots produce nodules, which are sometimes present in large numbers. Mr. M. J. Narasimhan¹ found from a microscopic examination that the nodules contain bacterial cells, indicating that they probably perform a useful function ; the production of root nodules appears to be characteristic of the genus, since they have been found also on other species of *Casuarina*. As a general rule the tree coppices badly, but if cut high the stools sometimes produce vigorous shoots. Mr. W. E. Copleston²

¹ Ind. Forester, xliv (1918), p. 265.

² Working Plan for the *Casuarina* Plantations near Honavar, 1910.

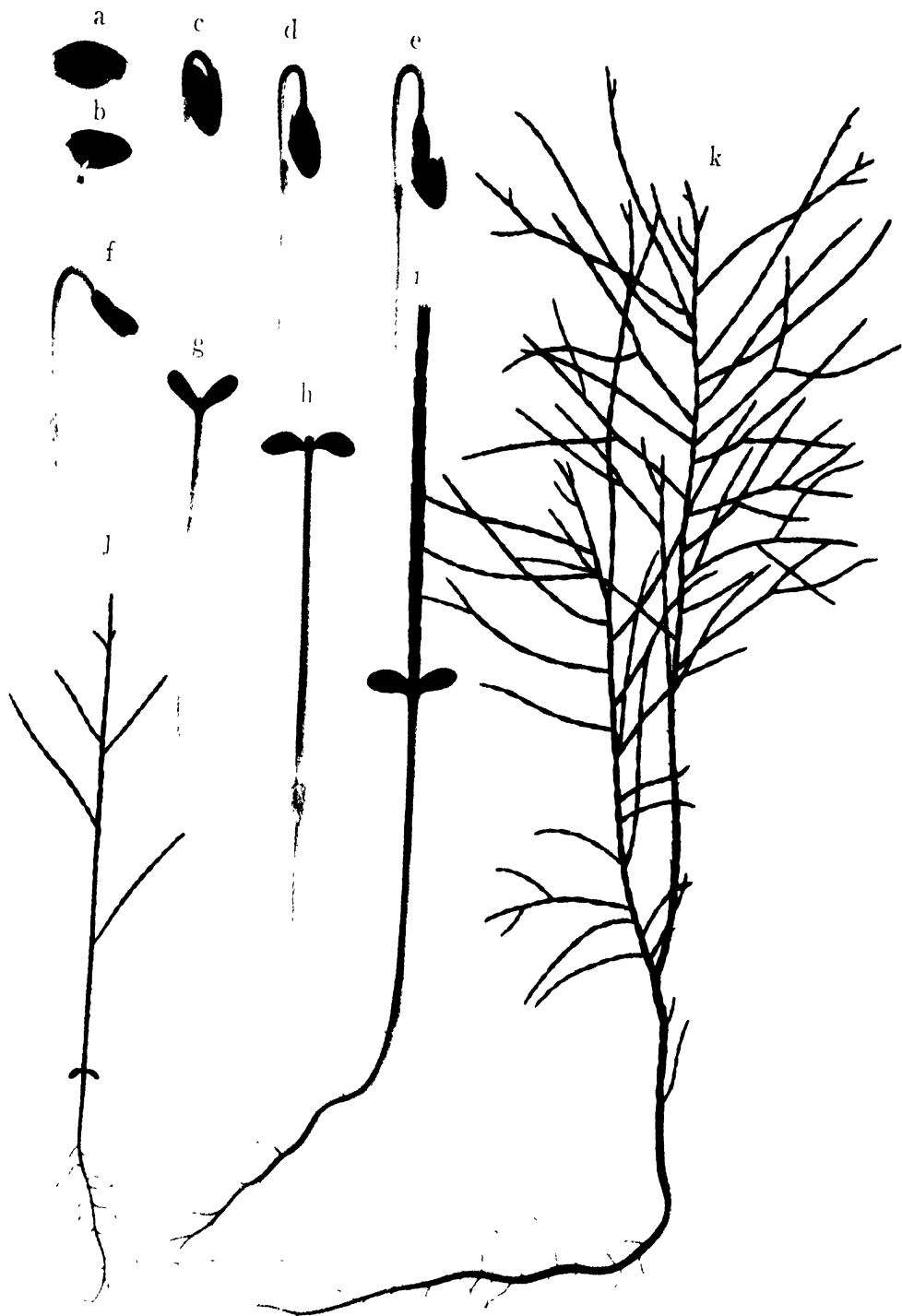


FIG. 332. *Casuarina equisetifolia* SEEDLING.

a - Achene $\times 2$ b - i - Germination stages $\times 2$ j - Seedling towards end of first season $\times \frac{3}{4}$
 k - Seedling towards end of second season $\times \frac{1}{4}$

mentions an exceptional case of coppicing in the Kasarkod plantation, North Kanara district, in which excellent coppice regrowth was obtained in a portion of the area close to the sea from trees which were ten or twelve years old when felled. Some of the coppice poles thirteen years old were 3 ft. in girth and over 80 ft. high. From some stumps as many as six strong shoots had developed, while from many stumps only one or two shoots were produced. Mr. P. M. Lushington¹ notes a case of vigorous layering and coppicing in a plantation in the Guntur district of Madras. Trees established from layers had a height of 15–20 ft. and a girth of 8½–18 in., although only two years old. An instance of vigorous coppicing was that of a stool about 2 ft. high and 30 in. in girth round the top, from a tree felled when about twelve years old; the stool had produced five large poles which had a height of 30 to 35 ft. and a girth of 13–27 in. at an age of fourteen years. The casuarina is subject to various pests and diseases, the chief of which are mentioned below in connexion with plantations. Young plants suffer to some extent from browsing by cattle, especially buffaloes.

NATURAL REPRODUCTION. The distribution of seed is effected, to some extent at least, by the agency of wind. The seed is produced in large quantities, and it has been suggested that it has been carried by sea originally from Australia to Java, Borneo, and other islands and thence to the coast of the Malay Peninsula and Burma; although this has not actually been proved, there seems to be nothing improbable in the suggestion.

As a general rule natural reproduction by seed is scanty or absent in the coast plantations of India, but in North Kanara natural seedlings appear in large quantities in open spaces along the edge of old plantations towards the end of the monsoon. The actual factors which influence natural reproduction require further study, but so far as experiments go, among conditions essential to success are (1) abundance of light, (2) porous sandy soil free from weed-growth, (3) absence of heavy rain during germination and the early life of the seedling, and (4) sufficient moisture in the soil to prevent mortality by drought during the first two or three years. Ants and other insects, as well as crabs, are no doubt responsible for a good deal of damage to seeds and seedlings under natural as under artificial conditions.

CASUARINA PLANTATIONS. All the most important casuarina plantations are situated along the sea-coast, both on the east and on the west side of the Indian Peninsula. There are some inland plantations, but the casuarina can hardly be regarded as a suitable plantation tree away from the coastal regions, though as a fast-growing and short-lived nurse for shade-bearing species it is sometimes useful.

The chief plantations formed by Government in the Madras Presidency are situated along the east coast, in the districts of Ganjam, Godavari, Kistna, Nellore, Chingleput, South Arcot, and Tanjore; plantations have also been formed in North Arcot near Vellore, some distance from the sea. The most important of the east coast plantations are those of Nellore, which in 1910 aggregated over 3,600 acres. On the west coast of Madras plantations have been formed to a small extent in South Canara, the oldest, the Ullal plantation, dating from 1868. There are also many private plantations in the Madras

¹ Inspection Note, 1912.

Presidency, and within recent years the Local Government has adopted the policy of handing over the management of casuarina plantations to private enterprise, with the result that the Government plantations have for some years past been in process of disposal to private individuals.

In the Bombay Presidency the planting of casuarina was commenced in 1868-9 at Karwar in the North Kanara district, and in 1886 in the Kolaba district near Alibag. These plantations have since been increased considerably in both districts, and have proved highly remunerative, the produce, in the shape of fuel, being conveyed by sea to Bombay. There are plantations on a smaller scale in the Ratnagiri district. A strip of sand along the shore at Puri in Orissa has recently been acquired for the formation of a casuarina plantation.

The coast plantations have been formed on pure sand, on low dunes or flat shores, or in a few cases on sand mixed with river silt. The subsoil water-level is never at a great depth, the actual depth varying ordinarily from about 4 to 12 ft. in the dry season. Where the sand deposit covers rich alluvial arable land, as in parts of the Nellore plantations, the growth is particularly fine. Figs. 333 to 336 show plantations in different stages in the North Kanara district, Bombay.

The method almost universally adopted for establishing casuarina plantations is to transplant seedlings raised in the nursery, usually in beds, but sometimes in boxes. The total cost of formation ordinarily varies from Rs. 20 to Rs. 25 per acre. In North Kanara many of the plantations have been raised from natural seedlings collected from around the existing plantations in November and kept in the nursery until the following June, when they are planted out; this method, however, is giving place to that of raising plants from seed in the nursery. Direct sowings do not answer, as the seedlings require special protection from heavy rain, drought, and insects. It may be mentioned that the casuarina makes a good hedge in sandy soil in coastal regions; the seedlings should be planted out about 1 ft. apart and encouraged to form a bushy growth by repeated trimming commenced at an early age. In the nursery the seed-beds should be well raised and composed of pulverized light porous sandy soil mixed with well-sifted mould, dry cowdung, and ashes: the surface should be well smoothed and the seeds sown broadcast on the surface and lightly covered with a sifted mixture of mould, dry manure, and ashes. In the Godavari district it is reckoned that 200 lb. of fruits give 24 lb. of seed, which is sufficient for 75 beds each 2 ft. by 6 ft. A covering of palm leaves, straw, or reeds is placed on the beds until germination is completed; germination ordinarily commences in about four to eight days, and the covering is removed in about ten to twenty days. Regular watering should be carried out. When the seedlings are about 2-4 in. high they are pricked out, the spacing adopted varying locally from 3 in. by 3 in. to 6 in. by 6 in. or even more. The age at which the seedlings are planted out varies locally from about six to eighteen months, but it is always advisable to keep the plants in the nursery as long as safety permits, in order to reduce the cost of subsequent watering in the plantation. The plants are transplanted into pits previously prepared, and often require to be supported for a year by stakes.

The dates of sowing, pricking out, and transplanting vary in different localities on the coast; planting on the west coast depends on the south-west



FIG. 333. *Casuarina equisetifolia* plantations in North Kanara (1) planting a cleared area at the beginning of the monsoon ; old plantation on left.



FIG. 334. *Casuarina equisetifolia* plantations in North Kanara : (2) planted area at end of first monsoon.



FIG. 335. *Casuarina equisetifolia* plantations in North Kanara (3) plants one year in nursery, three years in plantation.



FIG. 336. *Casuarina equisetifolia* plantations in North Kanara . (4) felling a mature plantation.

monsoon, while on the east coast it depends in several localities on the north-east monsoon. The following dates apply approximately :

Locality.	Sowing.	Pricking. out.	Transplanting.	Approximate age of plants when transplanted.
North Kanara	April	June	Commencement of SW. monsoon (June or begin- ning of July)	14 months.
Kolaba	Usually November (sometimes March-May)		Commencement of SW. monsoon (June or begin- ning of July)	18 months.
Madras east coast	February	May	Usually at commencement of NE. monsoon (October)	8 months.
			Sometimes in SW. monsoon (July)	5 months.

A system of making nursery-beds on raised platforms is in vogue in the Kolaba forest division of Bombay.¹ The seed-bed consists of a layer of soil 10 in. deep placed on a platform of latticed casuarina branchwood measuring $4\frac{1}{2}$ ft. by $4\frac{1}{2}$ ft., raised $2\frac{1}{2}$ ft. above the ground on four stout posts. The advantages secured by this method are immunity from insect attacks, good drainage, and removal of the seedlings without damage to their roots, by loosening the platform. The seed is usually sown in November, and a bed of the dimensions given produces at the end of twelve to eighteen months 500 to 700 seedlings with an average height of 5 ft. The growth under this system is very rapid, an average height of 10 in. and 25 in. being attained after three and six months respectively. Planting is carried out at the commencement of the monsoon, the seedlings being about eighteen months old.

For inland planting the seed should be sown in the nursery between February and April, and the seed-beds should be protected by coverings of thatch from sun and heavy rain. The seedlings should be pricked out 6 in. by 6 in. when 4 to 6 in. high and transplanted early in the second rainy season, when about fourteen to sixteen months old. It is often preferable, however, to raise the seedlings in boxes.

In existing plantations various spacings have been adopted, but the general rule now is to plant 8 ft. by 8 ft., 9 ft. by 9 ft., or 10 ft. by 10 ft. In some of the Bombay plantations triangular planting with a spacing of 12 ft. is the rule. At one time the spacing in force was as close as 6 ft. by 6 ft., but experience has shown that such close spacing is not advisable, since the branches begin to interlace after about three years, and early thinnings are necessary to prevent insect and fungus damage. It is now generally held that a spacing of less than 9 ft. by 9 ft. is neither necessary nor advisable.

After the seedlings have been transplanted from the nursery they require to be watered at once. Regular watering is also necessary for one, two, or three years after transplanting, according to the locality. Supplies of water are obtained from wells previously dug at intervals through the area planted ; the depth down to the water-level is as a rule not many feet in the coast plantations. Watering is done as far as possible in the evening. The intervals between successive waterings and the length of time for which watering is carried out must depend largely on the locality, and even in the same locality more copious watering is necessary on the dunes than in the hollows. Excessive watering should be guarded against, as it is considered to be a contributory

¹ V. D. P. Rebeiro in Ind. Forester, xxxix (1913), p. 380.

cause of fungus attacks. In North Kanara it is usual to water daily during the first dry season, while weakly plants are also watered during the second dry season where the water-level is deep. On the east coast it is usual to water for three years. In the first year watering is usually carried out for about ten months at intervals of one, two, or three days, according to requirements ; in the second year it is carried out for about six months (February–July), and in the third year for about four months (March–June), at similar intervals.

In the North Arcot plantations experiments carried out in 1909–10 showed that irrigation gave better results and proved cheaper than hand watering, although the plants were watered only once in five days instead of once in three days.

Pests and diseases in plantations. The artificial propagation of casuarina is attended with various difficulties in the shape of pests and diseases. Ants carry off the seeds from the seed-beds, and where this trouble is apprehended the seeds should be poisoned ; copper sulphate might be tried. In the Malay States the seeds are treated with a decoction of the root of *Derris elliptica*. Spreading ashes over the beds has some effect in preventing the attacks of ants and other insects. Failing this the seedlings may have to be reared in boxes raised on platforms protected from insects ; the platform system of Kolaba, described above, is said to prevent insect attacks. Seedlings in the nursery are much subject to the attacks of crickets, among which *Brachytrypes achatinus* has proved very destructive. They are guarded against in North Kanara by fencing the nursery round with a thick close fence 3 to 4 ft. high, and clearing all vegetation on a strip about 20 yds. wide outside the fence. The insects cannot as a rule hop over the fence ; those which do gain admittance have to be dug out of their burrows and killed. In the nurseries of the coast plantations small crabs are often troublesome in destroying seedlings ; where these are prevalent they have to be dug up daily in the nursery-beds and destroyed.

The plantations themselves are subject to various insect pests, of which *Arbela tetraonis*, the bark-eating caterpillar, and *Coelosterna scabrata*, a longicorn, are probably the worst. Young plants in some of the Madras plantations have been much damaged by the grubs of the rhinoceros beetle, *Oryctes rhinoceros* ; burning all rubbish before planting has proved a check. More serious than any of these, perhaps, is the root-fungus *Trichosporium vesiculosum*, which appears to be favoured by excessive watering and congestion ; thinnings commenced early and continued regularly have been found to check it to some extent. Insect and fungus attacks are dealt with by removing affected trees and grubbing up the stumps as soon as the attack reveals itself, but even this has in some cases failed to prevent the spread of the pests. In Nellore allowing a period of two years to elapse between felling and replanting is said to have had good results in the case of fungus attacks. A further expedient being tried in some of the Madras plantations is to plant other species of trees with the casuarina, either in regular mixture or in the form of belts between blocks of casuarina. The species most frequently planted are *Azadirachta indica*, *Eugenia Jambolana*, *Dalbergia Sissoo*, *Anacardium occidentale*, *Pongamia glabra*, *Pithecolobium dulce*, *Sapindus laurifolius*, and sometimes coco-nuts. These trees, besides assisting in segregation, are useful in attracting insectivorous birds, for in a dense casuarina plantation bird life is remarkably scarce.

Thinnings in plantations. Since the casuarina grows rapidly and is a strong light-demander, regular thinnings are necessary to ensure the proper development of the stems, which otherwise tend towards undue height-growth at the expense of volume production; they are equally necessary in order to minimize the danger of insect and fungus attacks. Where planting is done as close as 6 ft. by 6 ft. the first thinning is usually necessary after four years, and may even be required at three years of age; with wider spacing thinnings require to be commenced at an age of five to ten years, according to circumstances. In existing plantations the interval between thinnings is seldom more than ten years, and in some cases it has been as short as three years.

System of management and rotation. Casuarina plantations are worked under the clear-felling system with artificial reproduction by planting. An estimate of the rotation on correct financial lines was attempted in 1910 for the North Kanara plantations.¹ It was estimated from statistics of out-turn and price that the net rental at 4 per cent. culminated at twenty-seven years, while the greatest volume production was obtained with a rotation of thirty-three years; accordingly a rotation of thirty years was adopted, and this has been followed in the case of the coast plantations of Bombay generally. The results of working under the North Kanara working plan of 1910, however, have led to doubts as to the accuracy of the estimate, and in August 1916 Mr. Marjoribanks, in a paper read at the annual conference of southern circle forest officers, came to the conclusion that a shorter rotation, say one of ten years, with a thinning after five or six years, would probably yield a larger profit than the one prescribed. The question was considered in 1917 by Mr. Hart, who advocated the immediate reduction of the rotation tentatively to fifteen years.² In Madras the plantations have always been worked on short rotations; actually the rotations fixed at different times in various localities have varied from seven to fifteen years.

RATE OF GROWTH AND OUT-TURN. The growth is fast. The following estimates, from measurements in the North Kanara plantations, have been recorded in the appendix tables and curves of the working plan already alluded to:

Casuarina equisetifolia: rate of growth and out-turn, North Kanara plantations.

Age. years.	Mean basal diameter. in.	Corresponding mean girth. in.	Mean height of dominant stems. ft.	Volume per acre. cub. ft.	Mean annual volume increment per acre. cub. ft.	Current annual volume increment per acre for quin- quennial periods. cub. ft.
5	2.8	8.8	20	200	40	40
10	5.3	16.6	35	400	40	70
15	7.2	22.6	51	750	50	120
20	8.9	28.0	74	1,350	67	130
25	10.2	32.0	94	2,000	80	130
30	11.4	35.8	105	2,650	88	100
35	12.2	38.3	109	3,150	90	50
40	12.7	40.0	112	3,400	85	

¹ Working Plan for the Casuarina Plantations in the West Division, Kanara, R. S. Pearson, 1910.

² Note on a Tour of Inspection in some of the Forests of the Central, Northern, and Southern Circles, Bombay Presidency, G. S. Hart, C.I.E., Inspector-General of Forests, April 1917, p. 28.

The following measurements have been recorded by Mr. V. D. P. Rebeiro in plantations in Kolaba :¹

Casuarina equisetifolia : rate of growth, Kolaba plantations.

Approximate age (allowing for time in nursery).	Mean girth.	Mean height.
years.	in.	ft.
2-2½	3.5	11
3-3½	7	15
4-4½	8.5	17
5-5½	13.5	23
16-18	21	..
18-27	29	..
27-33	51	75

In the Madras plantations figures collected by Mr. E. P. Popert² in 1895 showed that the past yield varied from 50 tons per acre in Nellore to 28 tons in North Arcot, and he considered it safe to estimate a future out-turn of 40 tons per acre in coast plantations. More recent figures have shown that this estimate was over-sanguine, for in Nellore the actual average, under a ten-year rotation, for the ten years prior to 1910 was 25 tons per acre, and this from trees averaging a good deal more than ten years of age ; accordingly the estimated out-turn from 1910 onwards, under a rotation of eight years, was placed at 23 tons per acre, or nearly 2.9 tons per acre per annum over the whole area. If a ton be taken as equivalent to 50 cubic ft., the annual out-turn (i. e. the mean annual increment) per acre will be 144 cubic ft., which is greatly in excess of the estimate for North Kanara. Comparisons between the various records of out-turn given in working plans, however, are difficult to make, since they do not always state clearly whether yields from thinnings are taken into account.

Numerous statistics will be found in Mr. D. E. Hutchins's *Report on the Measurement of Rates of Growth of Casuarina in the Nellore District*, 1883.

ORDER LVIII. BETULACEAE

All the Indian trees of this order are Himalayan species, three, *Betula alnoides*, *Alnus nepalensis*, and *Carpinus viminea*, extending eastward to the hills of Burma. The most important Indian trees of this order are the birches and alders ; the hornbeams and hazels are represented by two species each, but none is sufficiently plentiful to be of much importance. The common hornbeam of the Himalaya is *Carpinus viminea*, Wall., which in general appearance much resembles the European hornbeam, *C. Betulus*, Linn. *C. faginea*, Lindl., is more local. The common Himalayan hazel is *Corylus Colurna*, Linn., which has a general resemblance to the European hazel, *C. Avellana*, Linn., and has an edible nut as good as that of the European species. *C. ferox*, Wall., is found in Nepal and Sikkim at 8,000-10,000 ft.

Genera 1. BETULA, Tourn. ; 2. ALNUS, Gaertn.

1. BETULA, Tourn.

There are three Indian birches, of which *B. cylindrostachys*, Gamble, is in all probability more than a mere variety of *B. alnoides*, Ham. All are hill

¹ Ind. Forester, xxxix (1913), p. 380.

² Note on Casuarina Planting, 1895.

species, *B. utilis*, Don, representing the highest limit of tree growth in the Himalaya. The fruits are small winged nuts arranged in catkins with deciduous scales, and a characteristic shared by all three species is their habit of springing up naturally on places where the soil has been exposed.

Species 1. *B. utilis*, Don ; 2. *B. alnoides*, Ham. ; 3. *B. cylindrostachys*, Gamble.

1. *Betula utilis*, Don. Syn. *B. Bhojpattra*, Wall. ; *B. Jacquemontii*, Spach. Himalayan silver birch. Vern. *Bhuj*, *bhujpattra*, Hind.

A moderate-sized deciduous tree, usually with a somewhat irregular bole ; sometimes a mere shrub. Leaves ovate acuminate, irregularly serrate, 2-3 in. long. Bark smooth, shining, reddish white or white, with white horizontal lenticels, the outer bark consisting of numerous thin papery layers exfoliating in broad horizontal rolls ; inner cortex red, moist. In all but young trees the bark of the lower part of the stem becomes rough and dark coloured. Wood pinkish white, even-grained, used for building in the inner Himalaya. The bark is used as paper for writing, packing, roofing, covering umbrellas, and other purposes. The twigs are used for rope bridges and the leaves are lopped for cattle fodder.

DISTRIBUTION, HABITAT, &C. This is the common birch of the higher levels of the inner Himalaya from Bhutan westwards, chiefly at 10,000-14,000 ft., but sometimes descending sporadically as low as 7,000 ft. and even to 6,000 ft. in the Kishenganga valley, Kashmir. It extends to China and western Tibet. At the higher elevations it is gregarious, occurring either in pure masses, often with an undergrowth of *Rhododendron campanulatum* or *R. Anthopogon*, or associated with the high-level silver fir (*Abies Webbiana*) and sometimes with juniper. In some localities, for example in Hazara, it is associated with the blue pine (*Pinus excelsa*), spruce (*Picea Morinda*), low-level silver fir (*Abies Pindrow*), brown oak (*Quercus semecarpifolia*), *Pyrus lanata*, *P. foliolosa*, and other trees, sometimes with an undergrowth of dwarf willow. In its gregarious state it marks the upper limit of tree vegetation on the uplands of the inner western Himalaya before the treeless snowy wastes begin (see Fig. 337). The birch forests occur on open exposed tracts which are under snow throughout the greater part of the winter. The tree is a strong light-demander. The young crops spring up on bare ground exposed by the scouring of snow or the accumulation of earth and rock débris. In such places natural reproduction is good, provided the young plants escape excessive grazing, which effectually prevents reproduction. The birch forests themselves are subject to constant erosion and scouring by snow, and the upper reaches of the snow-fed torrents are often piled up with the white trunks of the birch trees, which have been swept down by the sliding and melting snow. In some localities extensive damage is done to the birch forests by nomadic graziers, who lop and fell the trees for fodder and have been responsible for the clearance of whole tracts of forest. The excessive stripping of the bark for wrapping and other purposes also accounts for the death of many trees, and where the working of bark is to be carried out under control it should be insisted on that the outer bark should not be so completely removed as to expose the inner moist red cortex, and that a long enough interval should elapse between successive barkings to enable a sufficient thickness of outer papery bark to form again.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The leaves fall about October, turning a beautiful golden yellow before falling. The trees remain leafless during the winter, and the new leaves appear in April–May, at which time the birch forests can be distinguished from a distance by the delicate green colouring of the young foliage. The flowers appear with the young leaves, the male catkins drooping, 3–5 in. long, and the female spikes stiff, 1–1.3 in. long. The fruit ripens from August to October; the fruiting spikes are 1–1.5 in. long, containing numerous small narrow-winged nuts subtended by deeply 3-lobed bracts. The winged nuts are dispersed by wind or by sliding or melting snow, finding a germinating bed on newly exposed ground.

RATE OF GROWTH. The growth is slow. Gamble gives the average at about 15 rings per inch of radius, representing a mean annual girth increment of 0.42 in. A cross-section in the silvicultural museum at Dehra Dun showed 69 rings for a girth of 2 ft. 2 in., giving a mean annual girth increment of 0.38 in.

2. *Betula alnoides*, Ham. Syn. *B. acuminata*, Wall. Alder birch. Vern. *Sheori*, *kath bhuj*, *ban utis*, W. Him.

A moderate-sized to large deciduous tree with ovate or ovate-lanceolate sharply acuminate irregularly and doubly serrate leaves, 3–6 in. long. Bark grey or greyish brown, shining, with horizontal oblong lenticels, peeling off in rather stiff narrow horizontal bands. Wood close-grained, whitish to light brown, not much used at present.

DISTRIBUTION, HABITAT, &C. Himalaya from the Sutlej eastwards at 5,000–10,000 ft., Khasi hills, Manipur, and hills of Burma above 5,000 ft. This is the low-level birch of the Himalaya, its large leaves and somewhat sombre bark giving it the appearance of an alder. It often occurs sporadically in high forest mixed with oaks and other broad-leaved species as well as with conifers. It tends to become gregarious wherever conditions are favourable to its natural reproduction, that is, on landslips and other places where the soil has been newly exposed. Seedlings are frequently found on the sides of road-cuttings and similar places. Sporadic trees arise only from seedlings springing up on patches of new soil, since natural reproduction is incapable of appearing under a forest canopy or on weed-covered ground. This tree is not so pronounced a light-demander as *B. utilis*, and grows as a rule on more sheltered and moister situations than that species.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The tree is leafless in winter. The flowers are fully developed in March–April, and perhaps also at other times; the male and female catkins are more or less the same size, 2–5 in. long. The fruiting spikes ripen in May–June; the nut has a wing broader than itself, and can be dispersed to a considerable distance, judging by the manner in which seedlings spring up a long way from any seed-bearer.

RATE OF GROWTH. Gamble gives the growth as 10 rings per inch of radius in the north-west and $6\frac{1}{2}$ rings for Darjeeling wood; the corresponding mean annual girth increments are 0.63 and 0.96 in.

3. *Betula cylindrostachys*, Gamble. Low-level Darjeeling birch. Vern. *Saur*, Nep.; *Sunli*, Lepcha.

A tall deciduous tree, reaching over 120 ft. in height and 6 to 8 ft. in girth, with pink bark peeling off in large vertical flakes. Wood red, hard,

heavy. Gamble gives this as a low-level species of the Darjeeling hills, probably distinct from *B. alnoides*. It ascends to 6,000 ft., and descends even to the *tarai* forests, where it grows along streams. The seed ripens in March. Like *B. alnoides*, it tends to become gregarious on landslips and other places where the soil has been exposed, and is a suitable tree for afforesting such places at the lower elevations by means of direct sowings. At times it forms dense crops. Measurements made by Mr. E. Marsden in two crops in the Darjeeling hills in 1917 gave the following results :

Betula cylindrostachys : sample plot measurements, Darjeeling hills.

Age. years.	Number of stems per acre.	Mean girth at 4½ ft. from ground. ft. in.	Mean height. ft.	Solid volume per acre. cub. ft.	Remarks.
9	250	1 4	54	759	Open crop mixed with <i>Quercus semiserrata</i>
30	174	3 3.1	125	6,508	Unthinned.

These figures indicate a rapid rate of growth.

2. ALNUS, Gaertn.

The alders are readily distinguished from the birches by the persistent scales of the female spikes, which become woody in the cone-like fruit. The nuts are small and more or less winged. Both Indian species, like the birches, display the habit of springing up gregariously on new ground, *A. nitida* along the beds and banks of rivers and moist ravines, and *A. nepalensis* in similar places as well as on landslips and abandoned cultivation.

Species 1. *A. nepalensis*, Don ; 2. *A. nitida*, Endl.

1. *Alnus nepalensis*, Don. Nepalese alder. Vern. *Utis*, *kunis*, *kohi*, *kunsh*, W. Him. ; *Maibao*, Kachin hills.

A large deciduous tree, attaining a height of 80–100 ft. and a girth of 6 to 8 ft. Leaves 3–8 in. long, elliptical, entire or slightly denticulate. Bark silvery grey, darker in the forest. Wood pinkish, even-grained, soft, suitable for tea-boxes.

DISTRIBUTION, HABITAT, &c. Throughout the Himalaya from the Ravi eastwards at 3,000–9,000 ft., sometimes lower, Khasi hills and the hills of Upper Burma. In the western Himalaya it affects moist, shady ravines near water, usually in gregarious strips, but it is not so strictly confined to the beds of streams as *A. nitida*. In the eastern Himalaya and the hills of Burma it comes up readily on landslips and newly exposed soil generally, and also affects moist ravines. In the Darjeeling hills it quickly takes possession of landslips, often along with *Bucklandia populnea*, the result being a pure crop of alder or an overwood of the fast-growing alder with a lower story of the more slow-growing *Bucklandia*. Abandoned cultivated lands also become quickly covered with a pure crop of alder, as is strikingly exemplified in abandoned *taungya* clearings in the hills of Upper Burma.

FLOWERING AND FRUITING. The flowers are fully developed from September to November ; male catkins 4–10 in. long, in large terminal drooping panicles, female 0.2–0.3 in. long, in axillary racemes, rarely solitary. Fruiting cones 0.5–1 in. long by 0.3 in. in diameter. Nuts with a narrow membranous

wing. The fruits ripen in February–March, the empty cones remaining long on the tree.

ARTIFICIAL REPRODUCTION. The tree can be easily raised either by direct sowings on bare loose ground or by transplanting. Sowing should be done, *in situ* or in the nursery as the case may be, about February or March. Deer are found to be troublesome in young plantations, as they browse on the young plants as well as bark the saplings. In the Darjeeling hills the seed is sown broadcast on bare soil, and after the first year the seedlings grow rapidly, about 3 to 5 ft. a year. The tree is also occasionally planted in wet ravines where nothing else will grow, natural seedlings about 2 ft. high being usually transplanted. At Mongpoo great success is obtained by raising seedlings in the nursery and transplanting them when about 12 in. high. Seedlings can also be transplanted with success in June–July when 4–6 in. high and 3–4 months old. In the Darjeeling hills it has been found possible to transplant in the winter as well as in the rains.

In Burma this alder has been successfully established by line sowings in order to fill up grassy blanks in the forest reserves near Mogôk in the Ruby Mines district. An interesting system is in vogue among the *taungya*-cutting tribes in certain parts of the hills of the Bhamo and Myitkyina districts on the north-east frontier of Upper Burma. The crops raised in the temporary clearings are maize, cotton, or other hill crops. Alder seed is sown along with the crop or sown broadcast after it. A dense young crop of alder results; it requires weeding for three years and fire-protection for four, after which it requires no further attention. The rotation for shifting cultivation is reduced by this system from twelve years to eight, while the soil is enriched and protected from erosion and desiccation. Experiments have been tried in other parts of Upper Burma in sowing up *taungyas* in this manner, but it has been found that the alder will not grow below 5,000 ft. elevation, and failure is attributed in some localities to suppression by dense weed-growth or to the depredations of deer.

RATE OF GROWTH AND OUT-TURN. Under favourable conditions the growth is very rapid. Mr. J. L. Baker informs me that up to 6,000 ft. in the Darjeeling hills the alder attains a height of 50 ft. and a girth of 3 ft. in ten years, giving a mean annual girth increment of 3·6 in.

Gamble's specimens showed 3·6 rings per inch of radius, and he mentions a round of Sikkim wood with 2·4 rings per inch. Manson's Darjeeling working plan gives 3–4 rings per inch as the average. These figures give a mean annual girth increment of about 1·5 to 2·5 in.

The following measurements were made by Mr. E. Marsden in a young crop below Rangirum in the Darjeeling hills: age, ten years; stems per acre, 252; mean girth at 4½ ft. from ground, 1 ft. 4·1 in.; mean height, 51 ft.; solid volume per acre, 745 cubic ft. In a thinning carried out immediately before these measurements were made, 295 stems per acre, with a solid volume of 283 cubic ft., were removed.

2. *Alnus nitida*, Endl. West Himalayan alder. Vern. *Utis*, *kunis*, *kunsh*, *koish*, *sharol*, W. Him.

A large tree, attaining a height of 80–100 ft. and a girth of 6–12 ft. Leaves 4–5 in. long, elliptical ovate, acuminate, entire or obscurely crenate. Bark

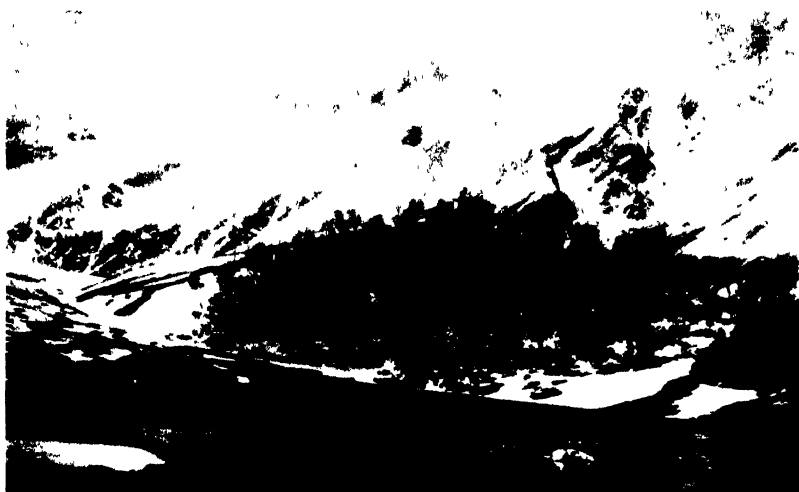


FIG. 337. *Betula utilis* towards upper limit of tree-growth, 12,000 ft.
Tehri Garhwal.



FIG. 338. *Alnus nitida* in the bed of a stream in *Pinus longifolia* forest,
Siran valley, Hazara



FIG. 339. Pure forest of *Quercus incana*, Kumaun hills.



FIG. 340. Mixture of *Pinus longifolia* and *Quercus incana*, the latter forming an under story to the former, Kumaun hills.

dark brown, rough with deep furrows. Wood reddish white, soft, close-grained. The tree sometimes attains large dimensions ; Mr. J. C. McDonnell¹ records one of 15 ft. girth in Kashmir.

DISTRIBUTION AND HABITAT. Western Himalaya from the Jumna westwards, usually at low elevations, most commonly below 6,000 ft., but ascending occasionally to 9,000 ft. This alder is always found in moist situations, mainly along the beds and banks of streams and rivers. It springs up gregariously on new land thrown up in the beds of rivers, where it forms pure crops, sometimes of considerable extent. It also springs up in strips along the banks of moist ravines and torrents, often in *Pinus longifolia* forest (see Fig. 338).

Henry² says that this is one of the few Himalayan broad-leaved trees which have succeeded in England, and that three thriving specimens, raised from seed sent by Mr. R. E. Ellis of the Indian Forest Department in 1882, are growing near the lake in Kew Gardens, the largest of which was 40 ft. high and 2 ft. 3 in. in girth about 1906.

FLOWERING AND FRUITING. The flowers are fully developed from August to October. Male catkins 4–10 in. long, about 4–6 together in terminal racemes ; female spikes about 0.3 in. long. Fruiting cones 0.7–1.5 in. long by 0.5 in. in diameter, in erect lateral racemes. Nut with a narrow thickened edge. The fruits ripen in November–December, the empty cones remaining long on the tree.

ARTIFICIAL REPRODUCTION. The tree is easily propagated from seed sown in moist shady nursery-beds about February, the seedlings being transplanted in moist situations when two or three years old. Natural seedlings are often available in plenty for transplanting purposes. The tree can be raised from cuttings put down in nursery-beds of moist sandy soil at the commencement of the rainy season and transplanted, after they are well rooted, in the winter or in the rainy season.

RATE OF GROWTH. A cross-section 3 ft. 4 in. in girth in the silvicultural museum at Dehra Dun had 41 rings, giving a mean annual girth increment of about 1 in. The tree in Kew Gardens mentioned above showed somewhat faster growth.

ORDER LIX. FAGACEAE

The two Indian genera in this order are *Quercus* and *Castanopsis*, of which the former is large and important and the latter is of somewhat less importance. The Spanish chestnut, *Castanea sativa*, Miller, is cultivated in India.

Genera 1. QUERCUS, Linn. ; 2. CASTANOPSIS, Spach ; 3. CASTANEA, Tourn.

1. QUERCUS, Linn.

A large genus of great importance in forestry in Europe, North America, Japan, and elsewhere. There are between 30 and 40 known species of oak in the Indian region ; of these about 24 are Burmese, though several of these extend into Manipur or the hills of and adjacent to Assam or Chittagong.

¹ Ind. Forester, xxix (1903), p. 152.

² Elwes and Henry, The Trees of Great Britain and Ireland, iv. 954 (1906).

while a few extend to the eastern Himalaya. The great majority of the oaks are hill species, some extending to high elevations; one or two, however, occur also at low elevations in forests not of any hill type, for example *Q. velutina*, Lindl., and *Q. semiserrata*, Roxb., which are found in low-level *indaing* (dry dipterocarp) forest in Burma.

Of a total of about ten oaks in the eastern Himalaya the most important are *Q. lamellosa*, Sm., *Q. pachyphylla*, Kurz, *Q. lineata*, Bl., and *Q. spicata*, Sm. Of the five species of the western Himalaya the three most important are *Q. incana*, Roxb., *Q. dilatata*, Lindl., and *Q. semecarpifolia*, Sm.

Several of the oaks are markedly gregarious, their occurrence defining regular zones of elevation; these zones are particularly well defined in the case of the three west Himalayan species just mentioned, which succeed each other from the lower to the higher elevations in the order given.

The oaks are deciduous or evergreen. The flowers are unisexual, rarely bisexual, monoecious, the males in pendulous catkins or erect spikes, the females 3- to 5-celled and styled with two ovules in each cell, enclosed in an involucre of numerous scales. The fruit (acorn), which ripens in the first or second year, is a nut with its lower part surrounded by a coriaceous or woody cup resulting from the growth of the involucre. The nut is one-seeded, the remaining ovules being abortive; in the case of *Q. semecarpifolia*, however, cases have been noticed where more than one fertile seed is present. The cotyledons are thick and fleshy; there is no albumen. Germination is hypogeous, the radicle emerging from the apex of the nut and the plumule extricating itself by the elongation of the cotyledonary petioles. In *Q. semecarpifolia* this elongation is of an abnormal character, the petioles remaining united in the form of a tube which may reach a length of 4 in. or more; the tube serves as a protection to the minute plumule, while the abnormal elongation of the united petioles enables the young plant to reach the soil as rapidly as possible. The acorns of most of the better known Indian oaks are much subject to the attacks of insects, but a slight boring of the cotyledons, provided the embryo is not damaged, does not appear to affect the fertility of the seed to any extent. The acorns are also eagerly devoured by birds and by bears, squirrels, rats, and other animals. These agencies often have a very prejudicial effect on natural reproduction.

So far as they have been studied, those acorns which lie for some time on the ground before germinating benefit by protection from the direct heat of the sun, under whose influence they tend to crack and to deteriorate. In this respect their shape and weight assist them to find their way into hollows, behind boulders and into other places where they receive the necessary protection, while in some cases the leaf-fall, occurring in the early part of the hot season, affords the fallen acorns the benefit of a covering of dead leaves.

The Indian oaks are important both economically and silviculturally. Those of the western Himalaya are at present utilized, where accessible, mainly for fuel, and to a very small extent for timber; silviculturally, however, some of them are of great use as nurses to and companions of the more important conifers with which they are frequently associated. In the eastern Himalaya some of the oaks are much in request for timber.

Species 1. *Q. incana*, Roxb.; 2. *Q. dilatata*, Lindl.; 3. *Q. semecarpifolia*,



FIG. 341. *Quercus incana*—FLOWERS AND FRUIT $\times \frac{3}{4}$

- a—New shoots and leaves and portion of last year's shoot, with male catkins (1), young female flowers at time of pollination (2), and female spikes one year old (3), March-June
 b- End of vigorous new shoot, showing slight development of young acorn in first season
 c—Young acorns, June-July, second season d— Young acorns, August, second season
 e—Ripe acorns, December-January, second season

Smith; 4. *Q. lanuginosa*, Don; 5. *Q. Ilex*, Linn.; 6. *Q. serrata*, Thunb.; 7. *Q. Griffithii*, Hook. f. and Thoms.; 8. *Q. glauca*, Thunb.; 9. *Q. lamellosa*, Smith; 10. *Q. lineata*, Bl.; 11. *Q. spicata*, Smith; 12. *Q. pachyphylla*, Kurn.

1. *Quercus incana*, Roxb. Grey oak, ban oak. Vern. *Bán, báj, Pb.*, U.P.; *Rhin, rin, rinj*, Haz., Jhelum; *Shiddar*, Kashm.

A moderate-sized to large evergreen tree with massive gnarled branches and a rounded crown, ordinarily attaining a girth of 4-6 ft. and a height of 40-60 ft., but occasionally attaining a girth of 8-10 ft. and a height of 80 ft. or more. Leaves 3-6 in. long, oblong or ovate lanceolate, acuminate, sharply serrate, coriaceous, dull green and glabrous above, densely white or grey tomentose beneath. Bark grey to greyish brown, longitudinally and transversely cracked, exfoliating in irregular oblong, sometimes rectangular scales, often moss-covered. Wood very hard, apt to warp and split, much used for fuel and charcoal, and employed to some extent for building and agricultural implements. In moist ravines with deep fertile soil this oak is a tall tree with a long clear bole, but in less favourable situations the bole is short; on dry slopes with shallow rocky soil the tree is stunted and gnarled. When grown in a close crop on fertile ground it produces a long straight bole and a narrow crown.

This is the commonest oak in the hill stations of the western Himalaya, where it is the principal source of fuel supply.

DISTRIBUTION AND HABITAT. Western Himalaya, extending eastward to Nepal, chiefly in the outer ranges at 4,000-8,000 ft., but occasionally descending lower in moist situations. It occurs in the Mothronwala swamp, Dehra Dun, at 1,900 ft. In the Kangra valley it descends in moist ravines to about 2,300 ft. In Garhwal it is found at Ratwadab on the Mandal river at about 2,000 ft. In the Lower Beas valley in Kulu it descends to 3,000 ft. It is cultivated with success at low elevations, and with a plentiful supply of water it will grow on the plains. At Dehra Dun (2,000 ft.) planted trees grow well, seed freely, and regenerate naturally. This oak grows on a variety of geological formations, including shale, gneiss, mica schist, quartzite, and limestone; it is very frequently found on the clayey soil produced by the decomposition of the shales which are so common a feature of the outer Himalayan ranges. It grows well also on micaceous sandy soil, the result of the decomposition of mica schist. It grows on all aspects, but attains its largest dimensions on cool northerly aspects with deep moist soil; on hot aspects with shallow rocky soil it is stunted, though here it often forms purer crops than on cooler and more fertile situations.

The ban oak usually grows gregariously, sometimes forming pure forests of considerable extent (Fig. 339). Of broad-leaved trees, among its commoner companions are *Rhododendron arboreum*, *Pieris ovalifolia*, *Populus ciliata*, *Ilex diphyrena*, *Cornus macrophylla*, *C. oblonga*, *C. capitata*, *Pyrus Pashia*, *Euonymus pendulus*, *E. tingens*, *Myrica Nagi*, *Acer oblongum*, *A. pictum*, *Albizzia mollis*, *Cedrela serrata*, *Ulmus Wallichiana*, *Morus serrata*, *Ficus nemoralis*, *Carpinus viminea*, *Corylus Colurna*, *Alnus nepalensis*, and *Betula alnoides*, while in moist shady situations are found various Lauraceae, such as *Machilus Duthiei*, *M. odoratissima*, *Phoebe lanceolata*, *Litsaea umbrosa*, and others. It is frequently associated towards its upper limits with *Quercus dilatata*, and on moist ground

at comparatively low elevations with *Q. glauca*; in the Kumaun hills *Q. lanuginosa* occurs locally in mixture with it. The ban oak is also frequently found associated with conifers, namely deodar (*Cedrus Deodara*) and blue pine (*Pinus excelsa*) at the higher elevations, and chir pine (*Pinus longifolia*) towards its lower limits. It is a very useful nurse to the deodar on hot slopes. Mixed forests of ban oak and chir pine are particularly common; here the oak either clings to the moister depressions, the pine occupying the spurs, or forms a lower story to the pine, which outgrows it. Fig. 340 shows oak forming an underwood to the pine.

On dry hot slopes where the crop is open the soil covering in ban oak forests usually consists of grass with occasional shrubs such as *Berberis*, *Indigofera*, *Desmodium*, and others. On more fertile ground there is usually a shrubby and herbaceous undergrowth: among the commoner shrubs are *Viburnum cotinifolium*, *V. stellulatum*, *Coriaria nepalensis*, *Berberis nepalensis*, *B. aristata*, *B. Lycium*, *Lonicera quinquelocularis*, *Jasminum humile*, *Maesa indica*, *Myrsine semiserrata*, *M. africana*, *Desmodium tiliaefolium*, *Rubus* spp., *Rosa macrophylla*, *R. moschata* (climber), *Prinsepia utilis*, *Daphne cannabina*, *Sarcococca pruniformis*, and the dwarf bamboo, *Arundinaria falcata*.

Where it descends to abnormally low elevations, *Quercus incana* is associated with typical low-level species. In the Dun it is found with *Eugenia Jambolana*, *Albizzia stipulata*, and other species of the local swamps. In the Kangra valley it is associated with *Dalbergia Sissoo*, *Acacia Catechu*, *Albizzia stipulata*, *Eugenia Jambolana*, *Ficus bengalensis*, and other low-level species, with an undergrowth of *Carissa spinarum*. In one locality it is found mixed with sal (*Shorea robusta*), the two forming an underwood to a crop of *Pinus longifolia*. In the Beas valley at 3,000 ft. it is found along with *Quercus glauca*, *Pistacia integerrima*, *Pyrus Pashia*, and *Olea cuspidata*.

In the normal habitat of this oak the climate is a temperate one; the shade temperature probably seldom exceeds 95° F., while it occasionally descends to below 20° F. At abnormally low elevations it experiences temperatures well over 100° F., but here its existence is rendered possible owing to the presence of ample soil moisture and to a comparatively heavy rainfall. In its normal habitat it ascends into the region of winter snow and descends below that region; the normal rainfall varies ordinarily from 40 to 95 inches, but at Dharmasala it is 117 inches. This oak does not extend into the inner arid valleys.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The time of sprouting of the new shoots and of flowering and fruiting varies considerably with elevation and aspect, and may also vary from year to year in the same locality, probably owing to climatic causes. Within the usual habitat of the tree the young shoots appear from the beginning of April to the middle of June; at Dehra Dun (about 2,000 ft.) they appear at the end of February or early in March. The young shoots and leaves are densely pubescent, and have a silvery grey or pale pink colour which gives the trees a conspicuous appearance at the season of sprouting. The growth of the young shoots is rapid, full length being attained as a rule in less than two months. In the second season the shoots become dark grey and woody, and gradually lose their pubescence. The old leaves fall for the most part from April to July or later, but leaf-



FIG. 342. *Quercus incana*.—SEEDLING $\times \frac{1}{2}$

a -Acorn b -Nut of acorn c - e Germination stages f Seedling towards end of first season
 g -Seedling in second season

shedding on a small scale may occur in the winter. The young leaves when fully developed can be readily distinguished from those of the previous year owing to the white or yellowish white tomentum on the under surface, which in the old leaves is a dirty grey colour (Fig. 341). The leaves have xerophytic characters in their stiff coriaceous texture and the tomentum on the under surface; the tender young leaves, protected by a dense pubescence, are often seen hanging vertically in hot dry weather.

The male catkins and female spikes appear on the new shoots. The male catkins (Fig. 341, *a*, 1) are pendulous, up to 6 in. long, in clusters of a few to several at the base of the new shoots or singly along the lower part of them; they ripen, and pollination takes place, from the end of March to the end of June, according to locality and season.

The female flowers (Fig. 341, *a*, 2) are small and inconspicuous, 0.1 in. in diameter more or less, single or two or more sessile on a common whitish tomentose peduncle, 0.3–0.6 in. long; the spikes are axillary on the upper part of the new shoots. There is little or no growth in the young acorns for a whole year after pollination, and at the commencement of the second season they may be found on the previous year's shoots (Fig. 341, *a*, 3), their size being more or less the same as that of the young female flowers which have just appeared. In specially vigorous shoots, however, an appreciable development is apparent even in the first season (Fig. 341, *b*); this is particularly the case where lopping has stimulated the growth of the young shoots.

During the second season the growth of the young acorns is rapid. They commence growing about April–May, and during June–July are usually about 0.2–0.3 in. in diameter (Fig. 341, *c*), increasing in August to about 0.4–0.5 in. in diameter; at this time the nut is still completely enclosed in the cup, which is greenish grey with brown-tipped imbricate scales (Fig. 341, *d*). The young acorns often remain abortive at this stage owing to insect attacks or other causes, and show no further development. The nuts commence to emerge from the cups from the end of August onwards, some becoming nearly full-sized, but still greenish grey, by the end of November or early December, though many have hardly emerged from the cup at that time. The acorns commence ripening in the latter half of December, and continue ripening during January. Many fall soon after ripening, but many remain some little time on the trees, falling gradually from February to May, though some remain even till June or July; the majority fall from the trees during the storms or heavy rain showers which occur from time to time in the spring. The ripe acorns are solitary or in pairs or small clusters on the greyish brown woody shoots of two years previously (Figs. 341, *e*, and 342, *a*). The nut (Fig. 342, *b*), 0.7–0.9 in. long, conico-ovoid, brown with a grey pubescence towards the apex, is about half inserted in the cup, which is rough, brown, and woody. About 200–250 nuts weigh 1 lb.

The time taken from the pollination of the female flower to the ripening of the acorn is about 1 year 7 months to 1 year 9 months. It is sometimes stated that the flowers develop and ripen into acorns in the same season. I have never met with an undoubted case of this, and probably the idea has arisen from the fact that shoots bearing ripe acorns are often succeeded by new shoots bearing young female flowers. The explanation is that shoots which

bear female spikes often produce no new growth the following year, though growth may be continued the year after, so that the successive shoots differ in age by two years, and not by one year, as might at first sight be supposed.

The acorns are greedily eaten by bears, monkeys, flying squirrels, rats, and birds, especially jays and nutcrackers. The squirrels and birds eat them both unripe and ripe. In 1916 the oaks in Simla gave promise of an abundant crop of acorns. Jays appeared in large numbers in November and remained throughout the winter devouring the unripe acorns; scarcely one was left to ripen, and those which did were all destroyed, and practically not a single acorn survived, the flying squirrels destroying those which escaped the attention of the jays.

In spite of the dangers to which the acorns are exposed good seed-years are fairly frequent. In Jaunsar in twelve consecutive years good seeding is recorded in five and poor seeding in seven years. In the Naini Tal forest division records exist regarding eight out of ten consecutive years, in which good seeding is recorded in four years and poor seeding in four years. In the Murree hills good seeding is recorded in four out of five consecutive years.

Fertile seed appears to be produced at a comparatively early age. The trees in a plantation in the Kaunli garden, Dehra Dun, although very crowded, seeded abundantly at twenty-six years of age, and produced plentiful reproduction; they have seeded regularly since. At Dharmasala in 1914 Khan Bahadur Imam-ud-din collected 48 sound seeds from coppice-shoots nine or ten years old and a similar number from a seedling tree of unknown age, and sowed them in two nursery beds; of the former, 26 germinated, and of the latter, 24.¹ If carefully stored in a cool, dry place and protected from insect attacks, the seed retains its fertility to a considerable extent for at least a year. Seed kept for one year at Dehra Dun was found to have a fertility of 60 per cent.

GERMINATION (Fig. 342, *c-e*). Hypogeous. The shell of the nut splits towards the apex and the radicle emerges, descending and forming a tap-root. Meanwhile the cotyledonary petioles elongate to about 0.2–0.3 in., separating and enabling the plumule to emerge and the young shoot to ascend. The fleshy cotyledons remain within the shell on or under the ground; they remain for a considerable time attached to the young plant, supplying it with nutriment in its earlier stages.

THE SEEDLING (Fig. 342).

Roots: primary root long, stout, terete, tapering, brown, wiry, flexuose, pubescent when young; lateral roots fairly numerous, short to long, brown, fibrous, pubescent, distributed down main root. *Hypocotyl* distinct from root, 0.1–0.2 in. long, stout, yellowish, pubescent, subterranean. *Cotyledons* subterranean: petiole 0.2–0.3 in. long, fleshy, flattened, yellow, pubescent; lamina 0.8–1.1 in. by 0.3–0.5 in., thick, fleshy, conferruminate, elliptical, obovate, apex rounded, base auricled by the prolongation of the lamina behind the petiole, outer faces convex, inner flattened in contact. *Stem* erect, terete, wiry, lower part yellowish brown turning brown, glabrous or pubescent, upper part green, grey tomentose; internodes 0.2–0.8 in. long. *Leaves* simple, alternate, petiolate, the first two or three small (under 0.5 in. long) or abortive. *Stipules* 0.1 in. long or less, linear acuminate, brown. Petiole 0.1 in. long,

¹ Ind. Forester, xli (1915), p. 132.

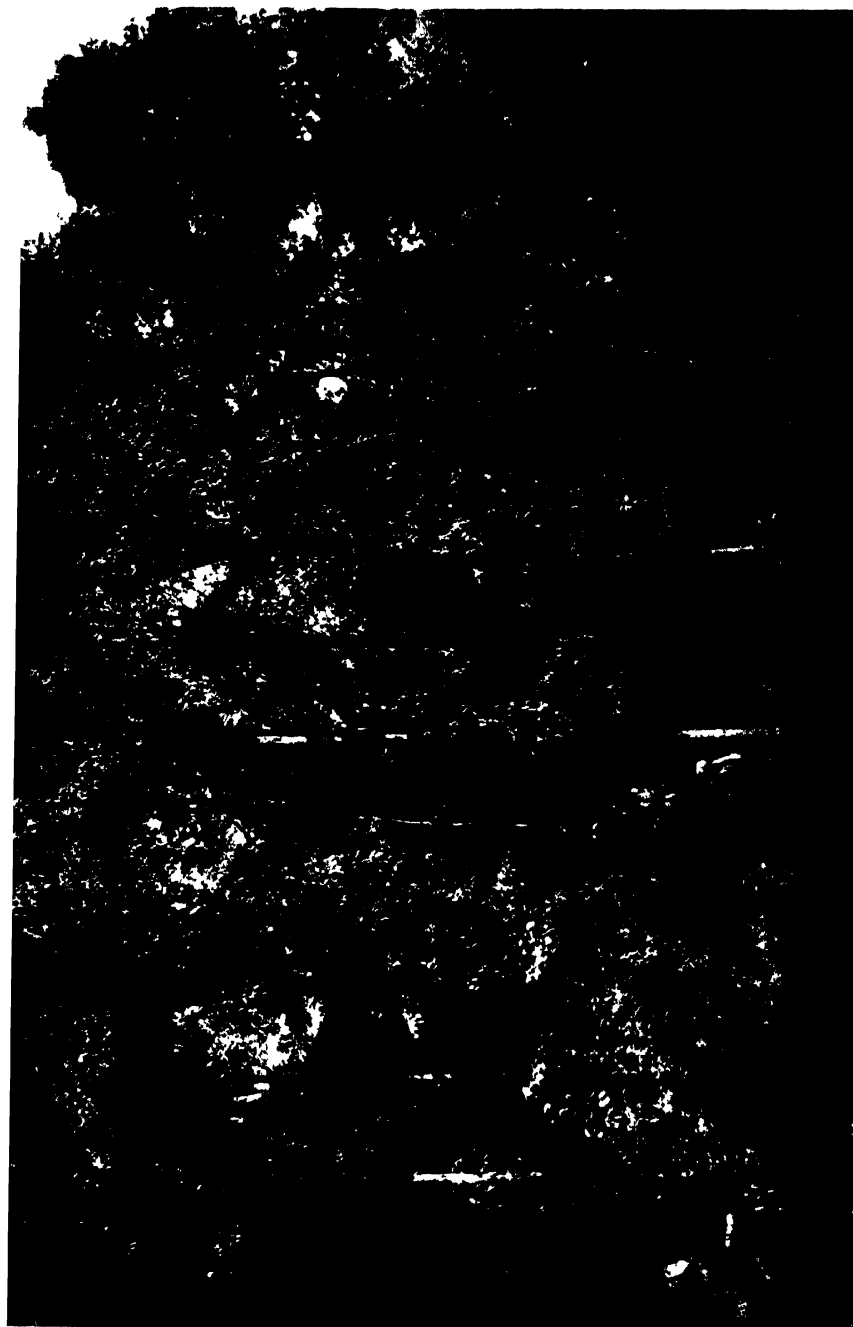


FIG 343 *Quercus incana*, plantation 34 years old, Kaunli, Dehra Dun

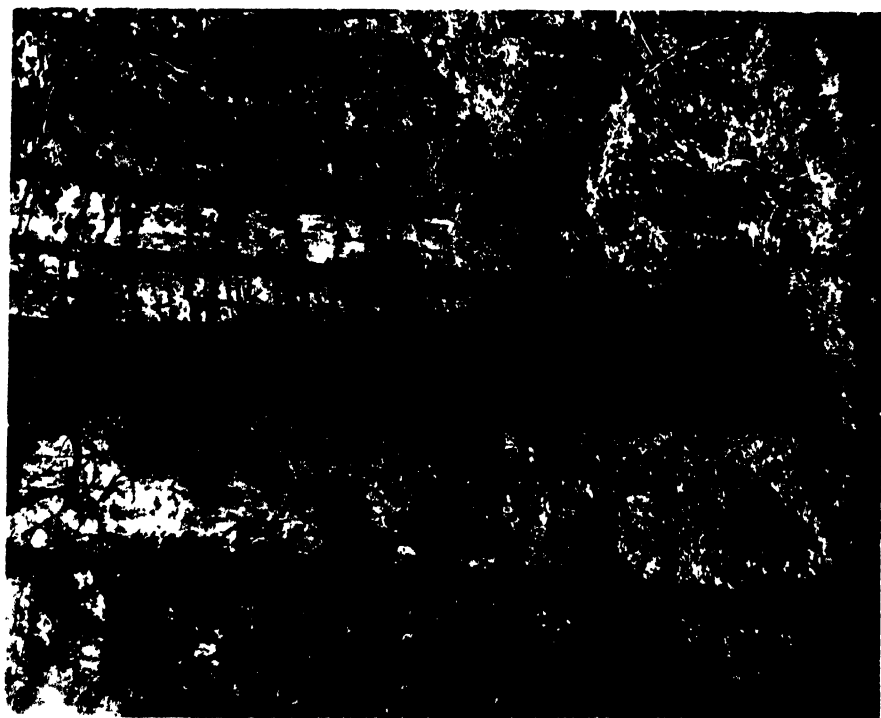


FIG. 344. *Quercus dilatata* tree, girth 16 ft., 4 in., height 144 ft., clear bole 72 ft., Jaunsai, United Provinces. Note man at base.



FIG. 345. *Quercus dilatata*, open crop of large trees, Hazara.

tomentose. Lamina (first season) 1.4–3 in. by 0.5–1 in., oblong or ovate lanceolate, acuminate, mucronate-serrate or dentate, coriaceous, green and glabrous or slightly pubescent above, densely whitish tomentose below; venation pinnate, lateral veins 6–10 pairs.

Under ordinary conditions the growth of the seedling is somewhat slow. During the first year natural seedlings attain a height of about 2 to 5 in. with 2–5 normal leaves. Plants raised from direct sowings in the forest in Jaunsar showed the following rate of growth :

Age in years	4	6	8	10
Mean height	0 ft. 11 in.	1 ft. 9 in.	2 ft. 8 in.	3 ft. 7 in.

Nursery seedlings grow somewhat faster, ordinarily attaining a height of 1 to 1½ ft. in three to four years. At Dehra Dun nursery seedlings constantly watered and weeded showed much more rapid growth, attaining a height of 2 to 3 ft. in two years and 5 ft. to 11 ft. 9 in. in four years; this exceptional growth, however, was due to constant attention combined with a climate warmer than this oak is accustomed to. Seedlings produce a stout taproot which attains a length of 6 to 12 in. in the first season. In their natural habitat seedlings commence the season's growth in May or early June.

For the first year or two seedlings stand a remarkable amount of shade, but thereafter they die off in excessive shade, and require moderate to full light for their best development. They are sensitive to drought, particularly during the first two years, when they die off in quantity in hot, dry situations. Seedlings are subject to the attacks of rats and crickets, which gnaw through the taproot. They grow well in grass and in moderate weed-growth, but develop best in clear hoed ground. Experiments at Dehra Dun showed that frequent weeding and loosening of the soil stimulates growth after the first year; during the first season its effect is not so marked, possibly because the seedlings obtain their nutriment to some extent from the fleshy cotyledons, and are not altogether dependent on the soil.

SILVICULTURAL CHARACTERS. The ban oak is a moderate light-demander. In this respect it stands between *Q. semecarpifolia*, which is more light-demanding, and *Q. dilatata*, which stands more shade. In the younger stages the ban oak stands a fair amount of shade, and even throughout its life it grows well under a light canopy of *Pinus longifolia* or *P. excelsa*. The root-system is massive, and on rocky ground is much gnarled and twisted; the tree is wind-firm in consequence. This oak usually coppices well up to a girth of about 2 to 3 ft. and sometimes more, but large trees as a rule fail to coppice; in the Naini Tal hills it has been found that trees over 3½ ft. in girth cannot be relied on to produce stool-shoots. Enumerations carried out in these hills in young coppice coupes in 1911 showed one to twelve with an average of four shoots per stool. The rate of growth of coppice-shoots is somewhat slow.

In its younger stages this oak suffers much from goat browsing, and cattle also eat the young shoots. Perhaps the worst form of injury to which the tree is subjected, however, is that of lopping for fodder, which is usually carried out in the winter. Trees regularly lopped lose their normal rounded crowns and produce numerous small shoots along the main branches, the crowns gradually thin out, and in time the tree dies. In the neighbourhood of villages many tracts formerly clothed with oak forest have become entirely denuded

of trees owing to the practice of lopping, and in many places the destruction can be observed in various stages of completeness.

In its natural home this oak resists ordinary frosts, but in the abnormal frost of 1905 it suffered considerably in some parts of the Himalaya, notably in the Murree hills. It is not hardy in England. It suffers severely from fire, particularly on steep slopes where there is a heavy inflammable undergrowth. The ban oak is subject to the attacks of certain loranthaceous parasites, particularly *Loranthus vestitus* and *Viscum japonicum*; the latter has been observed to spread rapidly, probably through the agency of birds.

NATURAL REPRODUCTION. Under natural conditions germination takes place early in the rainy season or after the early showers immediately preceding the monsoon, that is, as a rule in June and early July. It has been observed that heavy showers in the spring fail to stimulate germination, the temperature probably being too low. Germination is capable of taking place under heavy shade, and the seedlings survive for a time under moderate shade. Drought is probably the most adverse factor which the natural seedling has to contend with. In dry seasons in May and June numerous seedlings which have germinated the previous year may be found dying off in places exposed to the sun, or even in shady places where the soil is shallow and dry. In dry seasons similar mortality takes place in the autumn among seedlings which germinated a few months previously. The influence of the sun is no less marked in its effect on germination, for seeds lying in the open exposed for any length of time to the sun almost invariably crack and fail to germinate. This has been demonstrated clearly by an experiment at Dehra Dun in which 50 seeds were placed on the ground in each of four separate plots: (1) exposed to the sun, the ground being covered with short grass; (2) exposed to the sun, on bare ground; (3) under light shade, but exposed to the sun for part of the day; (4) under heavy shade. In plots (1), (2), and (3) not a single seed germinated, all being cracked by the sun. In plot (4) the percentage of success was 54, the best results being noticeable where the seed had become buried by the action of rain; seed germinating on the surface of the ground was found to be liable to destruction through insects eating the radicle.

Under natural conditions seedlings are often found in some quantity in slight depressions in which the seed accumulates and becomes covered with dead leaves and débris, or under the shade of bushes, or in moist places such as sheltered banks. Grass is quite favourable to the germination of the seed and the establishment of the seedling, provided the soil is not too dry. Natural seedlings are often found in quantity amongst loose débris at the foot of cliffs or steep slopes, the seed becoming covered and the taproot developing well in such ground. Frequent showers in the hot season following the year of germination are beneficial in providing moisture in the soil sufficient to ensure the survival of the seedling; a heavy snowfall probably has the same effect. It is probable also that the fact that the leaves are shed for the most part after the fall of the seeds and help to cover them and protect them from the sun assists in promoting successful germination; this is particularly noticeable in slight depressions where leaves collect.

Apart from natural influences, grazing and grass-cutting are very adverse factors in the establishment of reproduction. In grazed areas where the oak

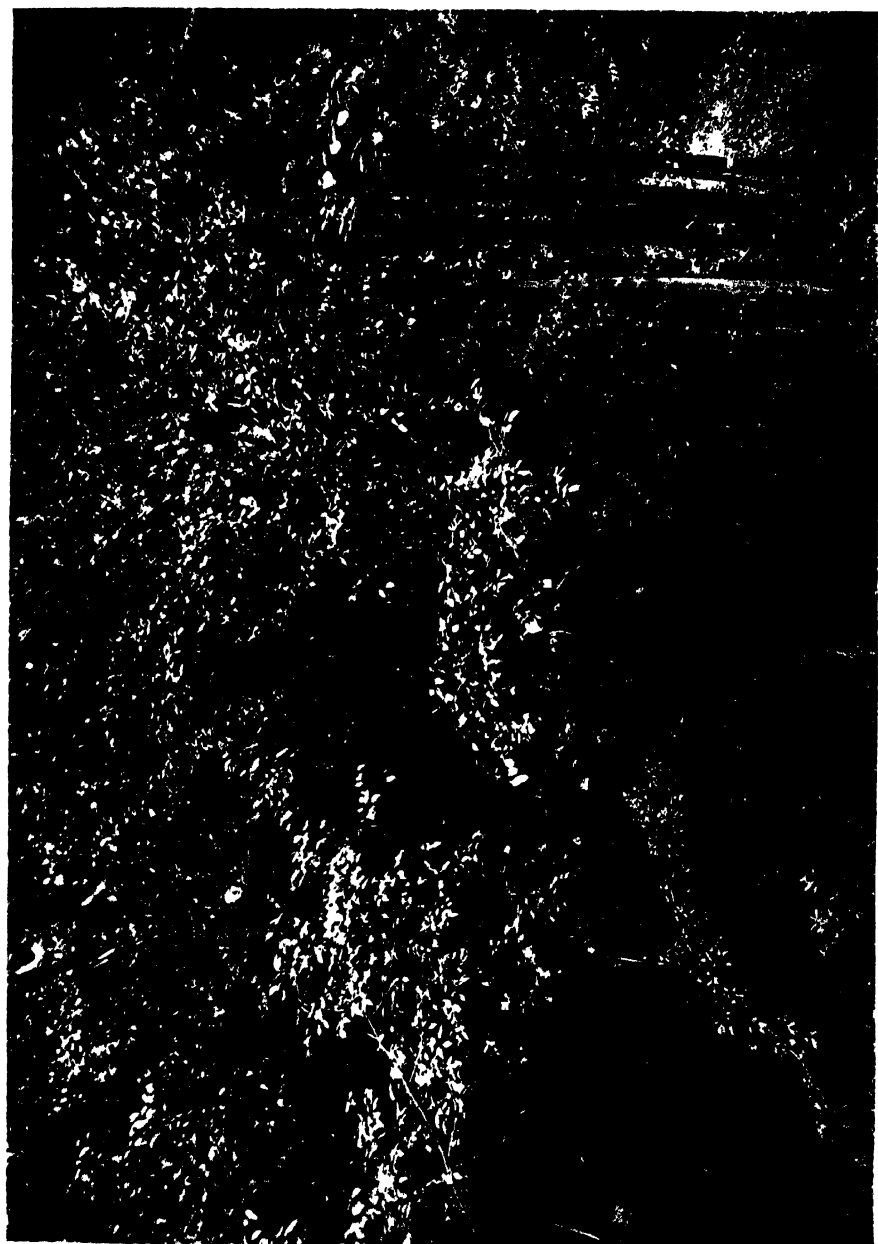


FIG. 346. *Quercus dilatata*, dense young natural crop, Kumaun hills



FIG. 347. *Quercus dilatata* pole crop Kumaun hills, mean girth 13 in. mean height 31 ft. just thinned to 2,180 stems (containing 2 176 cub. ft.) per acre, by removal of 540 stems (containing 530 cub. ft.) per acre.

is mixed with conifers instances may often be observed in which the crop is becoming converted to a purely coniferous one owing to the establishment of natural reproduction of the conifer while that of the oak fails. Natural reproduction may also suffer through the destruction of the acorns by birds and mammals already referred to.

ARTIFICIAL REPRODUCTION. This oak may be raised artificially either by dibbling *in situ* or by transplanting seedlings raised in the nursery. In the Naini Tal hills the former has proved more successful and economical than the latter. The winter or early spring is the best season for direct sowing. In hot dry situations the seed should be sown under the shade of bushes, boulders, or clumps of grass, and should be covered with earth to a depth of $\frac{1}{2}$ to 1 inch, not more; sowings, however, often fail on dry hot slopes, and success depends largely on the season being a wet one.

For raising seedlings in the nursery the seed should be sown in early spring (February or March) in drills 9 in. to 1 ft. apart in soil which has been well dug up; the seed should be covered to a depth of $\frac{1}{2}$ to 1 inch. Watering is advisable during the dry season, and the beds should be kept clear of weeds, the soil being loosened periodically. The seedlings will be ready for planting out in the third or fourth year, when about 12–15 in. high. Pricking out in the nursery is not essential, but if desired it should be carried out in the rainy season the year after sowing, the roots being slightly trimmed if necessary. The rainy season has been found to be the best season for transplanting in the forest, the results of winter planting having proved to be on the whole less successful; the latter, however, has been carried out quite successfully at Dehra Dun. Plantations require to be protected from grazing until the plants are out of reach of danger.

The ban oak has been raised artificially in many parts of the western Himalaya, usually in the form of sowings to restock small blanks. Fig. 343 shows a small plantation thirty-four years old at Kaunli, Dehra Dun; this plantation, which was formed in 1882–3 on fertile alluvial ground, has shown remarkably good growth, as will be seen from the figures quoted below.

SILVICULTURAL TREATMENT. Hitherto the ban oak, where worked on its own account, has been treated under the selection system, the exploitable girth being usually fixed at $4\frac{1}{2}$ or 5 ft., or under coppice-with-standards with a coppice rotation of twenty-five or thirty years. Often, however, the oak is worked as a secondary species to deodar or *Pinus longifolia*, and is cut or girdled in favour of the principal species. The coppice system is not successful unless the trees felled are of small size, say not more than 3 ft. in girth, and even then the proportion of failures is often considerable; for this reason supplementary artificial restocking by seed is always advisable in coppice coupes.

The selection system is not altogether unsuitable so far as the silvicultural requirements of the tree go, though from the point of view of ensuring reproduction and proper tending, and providing for closure to grazing, the system of successive regeneration fellings is preferable. It should be remembered that the seedling is of slow growth, requires shelter from the sun in the earlier stages, and can stand fairly heavy shade for a time, though it requires more light for its subsequent growth. This indicates that the seeding fellings should be carried out with caution, care being taken not to open out the canopy

severely until reproduction is well established. In most cases a fairly long regeneration period, say at least twenty-five years, is indicated. The case of the Kaunli plantation shows that under favourable conditions a crop of ban oak can be regenerated naturally with great success by a gradual opening of the canopy. The trees commenced seeding freely and regularly from an age of about twenty-six years, and the ground soon became carpeted with seedlings, although the canopy was dense; subsequently the canopy has been gradually opened out, and a promising even-aged young oak crop is present under the old crop. The conditions here are particularly favourable. Seed is produced in abundance, its fertility is high, and it is little, if at all, subjected to the attacks of animals; grazing is excluded, while the moist fertile soil under a complete canopy favours the establishment of the seedlings without risk of drought.

When the system of successive regeneration fellings is to be adopted in the irregular natural forests which exist at present it is probable that much supplementary artificial reproduction will be necessary. Closure to grazing and protection from fire will also be essential to success. Young even-aged crops are sometimes of considerable density, and in such crops thinnings form an important part of the tending operations necessary.

STATISTICAL. (1) *Coppice*. The mean height growth of coppice in Jaunsar, deduced from numerous measurements, chiefly in the Korwa forest, is estimated to be as follows:

Age in years	2	4	6	8	10	12	14	16
Mean height in ft.	1.9	3.7	5.5	6.9	7.7	8.5	9.3	10.0

Measurements made in 1911 in a coppice coupe six years old at Bhowali near Naini Tal gave an average height of 4 ft. 3 in. and a maximum height of 6 ft. 2 in.

(2) *High forest*. Systematic measurements in permanent high forest sample plots in even-aged and more or less fully stocked natural crops were commenced by the Forest Research Institute, Dehra Dun, in 1910-11, and the first periodical remeasurement was carried out in 1915-16. The plots in question, which are situated in the Naini Tal and West Almora forest divisions of the United Provinces, are 11 in number—7 unthinned, involving 442 measurements, and 4 thinned, involving 212 measurements. The following results have been compiled from these measurements:

Quercus incana: rate of growth in girth, Naini Tal and West Almora sample plots.

Age. years.	Thinned plots.			Unthinned plots.		
	Fastest.	Slowest.	Mean of all plots.	Fastest.	Slowest.	Mean of all plots.
	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
30	1 0 $\frac{1}{2}$	0 6	0 7 $\frac{1}{2}$	0 10	0 6	0 8
40	1 5 $\frac{1}{2}$	0 9	0 11	1 2 $\frac{1}{2}$	0 9 $\frac{1}{2}$	1 0 $\frac{1}{2}$
50	1 10 $\frac{1}{2}$	1 0	1 2 $\frac{1}{2}$	1 7 $\frac{1}{2}$	1 1	1 4 $\frac{1}{2}$
60	2 3 $\frac{1}{2}$	1 3	1 6 $\frac{1}{2}$	2 0 $\frac{1}{2}$	1 4 $\frac{1}{2}$	1 9
70	2 8 $\frac{1}{2}$	1 6	1 10 $\frac{1}{2}$	2 5 $\frac{1}{2}$	1 8 $\frac{1}{2}$	2 1 $\frac{1}{2}$
80	..	1 9 $\frac{1}{2}$	2 3 $\frac{1}{2}$	2 10 $\frac{1}{2}$	2 0 $\frac{1}{2}$	2 6 $\frac{1}{2}$
90	..	2 0 $\frac{1}{2}$	2 8 $\frac{1}{2}$	..	2 4 $\frac{1}{2}$	2 11 $\frac{1}{2}$
100	..	2 4 $\frac{1}{2}$	..	..	..	3 4 $\frac{1}{2}$
110	..	2 8 $\frac{1}{2}$	..	..	..	3 9 $\frac{1}{2}$
120	..	..	..	..	..	4 2 $\frac{1}{2}$



FIG. 348. *Quercus dilatata*-- FLOWERS AND FRUIT $\times \frac{3}{4}$

a New shoot and leaves, and portion of last year's shoot, with male catkins (1), young female spike (2) and female spike of previous year (3) April-May b-d Young acorns, showing successive stages of development, June-July, second season e Ripe acorns, August-October, second season

Volume figures in respect of these plots are recorded in *Indian Forest Records*, vol. vi, pt. ii, but these are not yet extensive enough to form the basis for general averages. In the above girth measurements the effect of thinnings has not yet become apparent. These measurements indicate that the growth of *Quercus incana* is slower than that of *Q. dilatata*.

The plantation at Kaunli, Dehra Dun, already referred to, has been measured twice with the following results : ¹

Quercus incana : measurements in Kaunli plantation, Dehra Dun.

Age. years.	Number of stems per acre after thinning.	Mean girth.		Mean height.	Solid volume per acre.	Intermediate yields per acre, from thinnings, solid volume.	
		ft.	in.			Periodic.	Total to date.
32	525	1	8.6	56	3,208	950	950
36	356	2	2.6	65	3,827	658	1,608

The growth in this plot is considerably faster than anything recorded in the normal habitat of this oak, and the volume production is also abnormally high.

The following estimated rate of growth, based on ring countings, applies to natural trees in Jaunsar : ²

Quercus incana : rate of growth, Jaunsar.

Age. years.	Mean girth.		Mean height. ft.
	ft.	in.	
20		..	5
40	1	1	14
60	2	1	22
80	3	2	30
100	3	11	38
120	4	9	47
140	5	7	56
160	6	3	65

2. *Quercus dilatata*, Lindl. Green oak, moru oak. Vern. *Moru*, W. Him. ; *Tilonj*, Kumaun, Garhwal ; *Barungi*, Haz.

A large evergreen tree with a dense crown of shining green foliage ; leaves 1.5-3 in. long, entire or spinous serrate, green on both surfaces. Bark of young trees smooth, grey to greyish brown, that of older trees dark grey or nearly black, scaly, with vertical and horizontal cracks, and exfoliating in rectangular or irregular scales. Wood very hard, used for building, agricultural implements, &c., as well as for fuel and charcoal.

The moru oak is the largest of the western Himalayan oaks, and under favourable conditions attains very large dimensions and produces a long straight bole. I measured the following trees in 1909 in the Siari block near Kouain, Jaunsar :

¹ Statistics compiled in the Silviculturist's Office, 1916-17, Ind. For. Rec., vol. vi, pt. v, 1918.

² Working Plan for the Jaunsar-Bawar Forests, P. H. Clutterbuck, 1901. (Girth measurements converted from diameter measurements recorded in the plan.)

No.	Girth at 4½ ft. from ground.		Total height.	Length of bole.	
	ft.	in.	ft.	ft.	
1	16	4	144	72	Height and length of bole measured with clinometer.
2	16	3	144	75	
3	14	3	144	..	
4	13	2	127	..	
5	12	0	125	..	Wind-fallen trees.
6	10	2	125	..	
7	10	0	122	61	

The lower part of tree No. 1 is shown in Fig. 344. Other girths of standing trees measured in the same locality were 17 ft. 8 in., 16 ft. 5 in., 16 ft. 3 in., 15 ft. 6 in., 14 ft. 9 in., 14 ft., 13 ft. 9 in., 12 ft., and 11 ft. 11 in. Mr. Gleadow¹ mentions a tree near Mundali in Jaunsar measuring 151 ft. in height and 17 ft. in girth.

DISTRIBUTION AND HABITAT. Western Himalaya from Nepal westwards, chiefly at 7,000–9,000 ft., but descending in some localities to about 5,500 ft., particularly in cool moist situations. It is very common in the Kumaun hills and from Jaunsar to Kulu. On the Dharmsala side of the Kangra hills it is absent except for a few scattered trees in Chota Bangahal. In the Murree hills it does not occur south of the Murree Dewal spur, though common on and north of that spur. The Burban forest near Murree affords a fine example of *Quercus dilatata* high forest extending over an area of about 56 acres; the soil is deep, moist, and fertile, and the trees are tall and of large girth. In Hazara this oak is common locally at about 6,000 to 8,500 ft. In Dir and Chitral it occurs locally in cool moist situations. It extends west into Afghanistan.

Although found on all aspects, the moru oak avoids very dry situations and favours moist, cool localities and northerly aspects. It attains its best development on deep rich, moist, well-drained soil. It often tends to regenerate in dense pure patches (see Fig. 346), and to grow gregariously in crops of varying extent. It is, however, also frequently found scattered in mixture with other trees, both coniferous and broad-leaved. Perhaps its commonest companion is the spruce (*Picea Morinda*), and the mixture is an excellent one, the oak being drawn up by the spruce and producing a long clean bole. The large oak shown in Fig. 344 is mixed with spruce, and the measurements of large trees given above were made in a mixed spruce and oak forest. Other coniferous trees associated with the oak are the blue pine (*Pinus excelsa*), the deodar (*Cedrus Deodara*), and the silver fir (*Abies Pindrow*), while there is often an undergrowth of yew (*Taxus baccata*). Among broad-leaved trees the commoner associates are *Aesculus indica*, *Acer Caesium*, *A. pictum*, and other maples, *Ulmus Wallichiana*, *Prunus Padus*, *Cornus macrophylla*, *C. capitata*, *Euonymus pendulus*, *E. tingens*, *Juglans regia*, *Corylus Colurna*, *Betula alnoides*, and *Populus ciliata*; at its lower limits it mixes freely with *Quercus incana*. In moru oak forests there is often a rich undergrowth of herbaceous plants and shrubs, such as *Viburnum*, *Lonicera*, *Rubus*, *Rosa*, *Daphne cannabina*, *Indigofera*, *Desmodium*, *Strobilanthes*, and various ferns, with the dwarf bamboos *Arundinaria falcata* or *A. spathiflora*. Fig. 345 shows a typical though somewhat open crop of oak with a shrubby undergrowth; a few saplings of *Pinus excelsa* may be seen making their way up in a gap on the right.

¹ Forest School Tour in Jaunsar, 1898–9, p. 49.

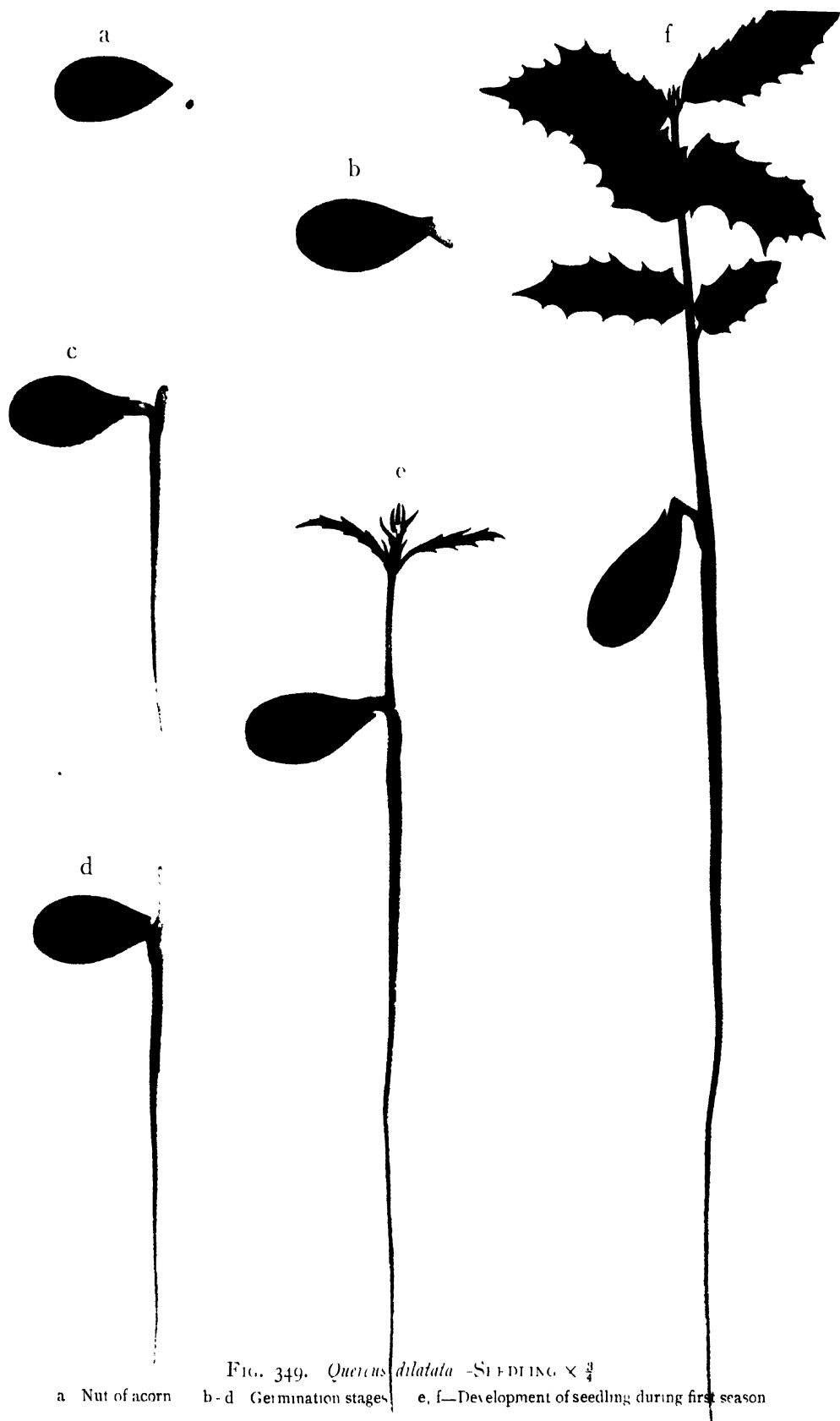


FIG. 349. *Quercus dilatata* -SEEDLING $\times \frac{3}{4}$

a Nut of acorn

b - d Germination stages

e, f—Development of seedling during first season

The home of this oak is in temperate regions, where there is usually a fairly heavy winter snowfall. The maximum shade temperature probably seldom exceeds 90° F., and the minimum is often below 20° F. The normal rainfall, including equivalent snowfall, varies for the most part from 45 to 95 in.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The old leaves fall principally during May and June, but some may commence falling earlier, while some may persist later. The new green shoots appear late in March to early in May, according to elevation; they grow rapidly, attaining full size within two months.

The male catkins and female spikes appear on the new shoots, the former maturing and pollination taking place in April–May. The male catkins (Fig. 348, *a*, 1) are in pendulous clusters 2–3 in. long at the base of the new shoots. The small female flowers, usually several in number, are sessile on a common penduncle 0.5–1.5 in. long, the spikes being axillary in the upper parts of the new shoots (Fig. 348, *a*, 2). The shoots which bear female spikes often produce no new growth the following year.

There is little or no growth in the young acorns during the first season; about a year after the appearance of the flowers they may be found on the previous year's shoots, only just commencing to grow (Fig. 348, *a*, 3). From that time onwards their growth is rapid. The nut remains enclosed in the cup until June–July, when it commences to emerge (Fig. 348, *b*, *c*, *d*); at this time the nut is bright green and the cup is pale green or greyish green with prominent imbricate scales.

The acorns (Fig. 348, *e*) are solitary or two or more together on the previous year's shoots. They commence ripening in August, and by October most of them have fallen and many have germinated; at the higher elevations they often do not ripen until well on in October, germination taking place at the end of that month or even later. The nuts (Fig. 349, *a*) are 0.6–1.3 in. long by 0.4–0.7 in. in diameter, ovoid or oblong, brown to dark greenish brown, glabrous and shining; the cups are 0.4–0.8 in. in diameter, grey, woody, with closely adpressed scales, and enclose about one-third to nearly one-half of the nut. The time taken from the pollination of the female flower to the ripening of the acorn is thus about 15–17 months.

The acorns are subject to insect attacks. They are also devoured by animals and birds, but as they ripen before the winter and germinate at once, they do not suffer nearly so much as do acorns, like those of *Q. incana* and various other species, which ripen in the winter when food is scarce and germinate some time after ripening. Good seed-years are fairly frequent. In Jaunsar records for fourteen years out of seventeen consecutive years showed good seeding in six and poor to moderate seeding in eight years.

GERMINATION (Fig. 349, *b–d*). Hypogeous. The nut splits towards the apex and the radicle emerges, descending and forming a long stout taproot. Meanwhile the cotyledonary petioles elongate to 0.3–0.5 in., sometimes longer, and separate, enabling the plumule to emerge and the young shoot to ascend. The fleshy cotyledons remain within the shell on or under the ground; they remain attached to the young plant for a considerable time, providing it in its earlier stages with nutriment.

The germination of this oak shows a transition stage between that of the lower-level oaks (*Q. incana*, *Q. glauca*, and *Q. lanuginosa*) and that of the

high-level oak (*Q. semecarpifolia*) ; thus it tends to form cotyledonary petioles long enough to indicate an effort to push the embryo plant down towards the soil, but in a lesser degree than in the case of *Q. semecarpifolia*, while moreover the cotyledonary petioles are separate and not united into a tube as in the case of the latter.

THE SEEDLING (Fig. 349).

Roots : primary root long, thick, terete, tapering, woody ; lateral roots few to moderate in number, fibrous, distributed down main root. *Hypocotyl* scarcely distinguishable. *Cotyledons* subterranean, remaining within the nut. Petiole 0.4–0.6 in. long, inner surface flattened, slightly pubescent to glabrescent. Lamina 0.7–1.1 in. by 0.4–0.6 in., thick, fleshy, obovate or oblong, apex rounded, base prolonged in one or two points, outer surface rounded, grooved or wrinkled, inner flattened in contact. *Stem* erect, terete, woody, green turning brown, tomentose ; internodes 0.2–1.4 in. long. *Leaves* simple, alternate, or earlier ones sub-opposite. Petiole 0.1–0.2 in. long, tomentose. Lamina 0.7–2.2 in. by 0.4–1.2 in., oblong or oblong lanceolate, acuminate, spinous serrate ; young leaves tender, yellowish green to reddish brown, stellate pubescent ; older leaves stiff, glabrous, green above and beneath.

During the first season seedlings ordinarily attain a height of 2–4 in., with about three to ten leaves and a stout taproot 6–10 in. long. Subsequent growth is somewhat faster, a height of 1½–2 ft. being attained in five years. Seedlings stand much shade ; they establish themselves well under a moderate growth of shrubby weeds, but are apt to damp off under dense herbaceous weed-growth and on badly drained ground. Seedlings are sensitive to drought. They are subject to the attacks of an insect, believed to be a cricket, which bites through the root collum and kills the seedlings during the first two seasons.

SILVICULTURAL CHARACTERS. The moru oak stands more shade than either *Quercus incana* or *Q. semecarpifolia*. Its root-system is less massive than in the case of those species, and trees are not infrequently thrown by wind. Its coppicing power is uncertain. In some localities trees coppice well up to about 3 ft. in girth, but larger trees often fail to produce stool-shoots. In the Murree hills even trees under 3 ft. in girth seldom produce coppice-shoots ; since many of the trees in that locality are of coppice origin it has been suggested that this oak does not coppice more than once. The moru oak, like *Q. incana*, is much subjected to lopping, and in village lands it suffers much from this practice. Young plants and coppice-shoots are readily browsed, particularly by goats.

NATURAL REPRODUCTION. Under natural conditions the seed germinates soon after falling during and at the end of the rainy season, from August to October. The ground is then moist and conditions for germination are favourable ; in dry places exposed to the sun, however, the seed may fail to germinate. In a good seed-year the ground in the neighbourhood of seed-bearers at this time is thickly carpeted with young seedlings in various stages of germination and development, although a good deal of the seed may be destroyed by insects before reaching the ground. In places exposed to the sun many of these seedlings die off in the ensuing dry season, but in moist shady places the majority survive, and the young oak crops establish themselves in dense thickets. Such thickets are found not only under shade but also on open grassy slopes, chiefly on the downhill side of the seed-bearers, provided the



FIG. 350. *Quercus semecarpifolia* trees on ridge at 9,000 ft , Jaunsar.



FIG. 351. *Quercus semecarpifolia* forest of good quality, opened out several years previously and containing much natural reproduction, Jaunsar.

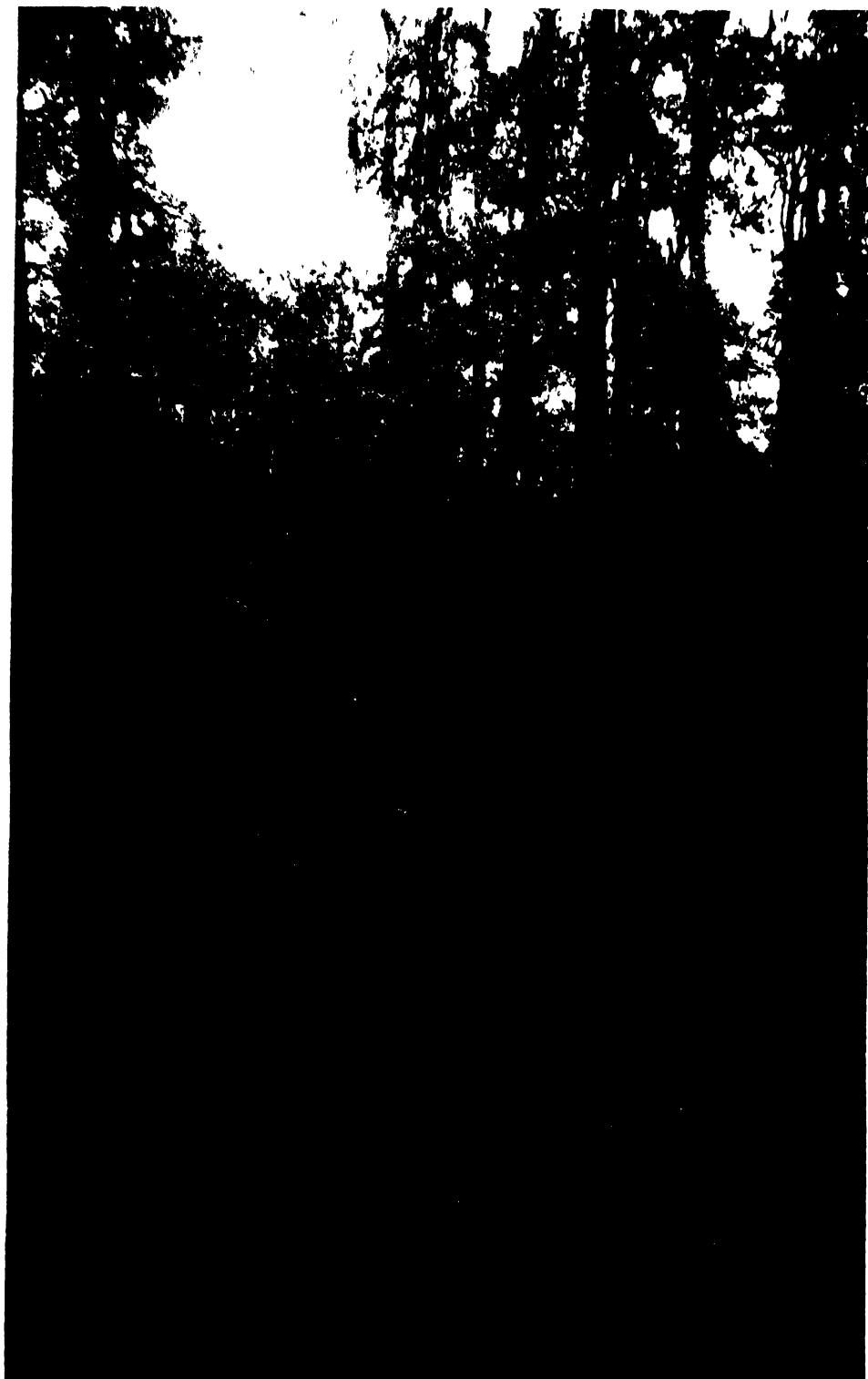


FIG. 352. *Quercus semecarpifolia*, dense natural reproduction established as a result of a heavy opening of the canopy, Jaunsar.

aspect and situation are not too dry. Although thickets of young oak appear under fairly heavy shade, these establish themselves most freely where there are moderate to wide gaps in the canopy. Seedlings are not as a rule found at any great distance from seed-bearers, the reason being not only that the seed is heavy, but also that it germinates soon after falling, and therefore has less chance of being transported to any distance, by rainwater or otherwise, than in the case of seeds which lie on the ground some time before germinating. Reproduction is not as a rule good where there is a heavy growth of herbaceous weeds, although a moderate shrubby weed-growth does not appear to retard it to any great extent. Exclusion of grazing is necessary in order to ensure good natural reproduction.

ARTIFICIAL REPRODUCTION. This oak can be cultivated successfully either by direct sowing or by transplanting from the nursery. In either case the seed should be sown as soon as it ripens, about August and September. For transplanting purposes nursery-raised seedlings two years old are usually employed, the planting being done in the rainy season. Good results, however, can be attained by transplanting natural seedlings, which are often available in quantity.

Experience in Jaunsar has shown that sowing and planting on hot, dry slopes result in failure, but that if carried out on moist loamy soil in cool situations, they can be accomplished with complete success ; the usual spacing adopted has been 5 ft. by 5 ft., which is probably not too close if clean-stemmed poles are required.

SILVICULTURAL TREATMENT. Hitherto this oak has been worked, along with its associates, either as coppice-with-standards or under selection fellings. Coppice fellings, as already noted, are uncertain. Selection fellings are not unsuitable, but in view of the natural tendency of this oak to regenerate in even-aged masses, which owing to their density require special tending, the concentrated working and attention afforded by the system of successive regeneration fellings would appear to be preferable to the more diffuse working under the selection system, except perhaps on very limited areas. In carrying out regeneration fellings every opportunity should be taken to free the groups of young oak as soon as they establish themselves, since they develop best with abundant overhead light. Thinnings in these dense thickets require to be commenced fairly early and repeated at regular intervals. Fig. 347 shows a young pole crop which has just been thinned.

RATE OF GROWTH. The following statement gives the mean rate of growth of transplants in plantations at Matkangra and Bodyar in Jaunsar, as well as of plants left to grow up in the nursery in the form of thickets :

Quercus dilatata : rate of growth in plantations, Jaunsar.

Age. (from seed). years.	Mean height.				Mean girth.			
	Matkangra.		Bodyar.		Matkangra.		Bodyar.	
	Plantation.	Nursery.	Plantation.	Nursery.	Plantation.	Nursery.	Plantation.	Nursery.
	ft.	ft.	ft.	ft.	in.	in.	in.	in.
5	2	3.5	2	3				
10	5.5	8.5	4	6.5				
15	9.5	14.5	7.5	11.5		12		
20	14	20.5	..	..				
25	18.5	26.5	..	..				
30	23	..	..	..				

The Bodyar plantation was formed in a somewhat unfavourable locality on a rocky slope. The plants left in the nurseries formed dense thickets, those in the Matkangra nursery being particularly vigorous.

Systematic measurements in permanent high forest sample plots in the Naini Tal forest division were commenced in 1911-12 by the Forest Research Institute, Dehra Dun. The first quinquennial remeasurement was carried out in 1915-16, and the average growth in five unthinned sample plots in even-aged and more or less fully stocked natural crops involving 253 measurements was found to be as follows :

Quercus dilatata : rate of growth in high forest sample plots, Naini Tal.

Age.	Mean girth.	Age.	Mean girth.
years.	ft. in.	years.	ft. in.
30	1 0	60	2 6.2
40	1 5.5	70	3 2
50	1 11.2	80	3 9.5

A more rapid rate of growth would doubtless be attained in the case of regularly thinned crops. Subsequent remeasurements will produce more reliable results, but in the meantime the increments deduced for one quinquennial period are sufficient for a rough estimate of the growth. These measurements indicate that the growth of *Q. dilatata* is more rapid than that of *Q. incana*.

The Jaunsar working plan ¹ gives the following estimated rate of growth, based on ring countings :

Quercus dilatata : rate of growth, Jaunsar.

Age.	Mean girth.	Mean height.	Age.	Mean girth.	Mean height.
years.	ft. in.	ft.	years.	ft. in.	ft.
20	..	5	100	3 11	47
40	1 1	15	120	4 9	58
60	2 1	25	140	5 7	69
80	3 2	36	160	6 3	80

3. *Quercus semecarpifolia*, Smith. Brown oak, kharshu oak. Vern. *Kharshu*, *banjar*, *kreu*, *chor*, W. Him. ; *Khusra*, Bhut.

A large tree, evergreen or nearly so, forming in favourable localities a long clean bole, but at its upper limit and on exposed ridges often stunted and gnarled. Leaves 2-4 in. long, elliptical or oblong, spinous-toothed in young trees and coppice-shoots, often entire on older trees, stiffly coriaceous, glabrous and dark green above, brown tomentose (in young leaves nearly white tomentose) beneath. Bark dark grey, rough, with small quadrangular or irregular scales. The branches are often festooned with mosses and lichens. Wood very hard, of good quality but not much used as timber, though locally employed for building and agricultural implements ; an excellent fuel and charcoal wood.

In favourable situations this oak ordinarily reaches a height of 80-90 ft. and a girth of 7 ft. or more, but larger trees are occasionally met with. In the Mohna forest near Chakrata, Mr. A. Smythies measured a tree 117 ft. high

¹ Working Plan for the Jaunsar-Bawar Forests, P. H. Clutterbuck, 1901. (Girth measurements converted from diameter measurements recorded in the plan.)



FIG. 353. *Quercus semecarpifolia* — FLOWERS AND FRUIT $\times \frac{3}{4}$

- a New shoot and leaves and portion of last year's shoot and leaves, with male catkins (1), young female spike (2), and female spike of previous year (3), end of May - June
 b Half-grown acorns June second season c Ripe acorns, end of June - July, second season

and an old stump 15 ft. in girth.¹ In the same forest I measured in 1909 two trees 101 and 102 ft. in height and a third 13 ft. 7 in. in girth and 74 ft. high ; the last was quite hollow. On the ridge above Deota in Tehri Garhwal, Mr. Gleadow² records trees with girths of 12, 13½, 14½, and 16½ ft., the last a dead tree. Mr. E. M. Coventry³ records two trees in the Muril forest, Jubal state, 13 ft. 5 in. and 13 ft. 10 in. in girth. In 1918 I measured a tree 16 ft. 8 in. in girth near Lohar Baik in Hazara ; this tree, however, was hollow.

The kharshu oak promises to be an important yielder of tannin. In 1918 Mr. Pilgrim found as much as 23·65 per cent. of tannin in samples of branch bark, although stem bark yielded only 11·63 per cent. English oak bark seldom gives more than 14 per cent., so that the tannin content of kharshu branch bark is remarkable ; in addition the ratio of soluble non-tannin to tannin was found to be only 1·9, which is very low.

DISTRIBUTION AND HABITAT. This oak is found throughout the Himalaya from Bhutan westwards, chiefly at 8,000–12,000 ft., on the Burma-Manipur frontier at 8,000–10,000 ft., and in China. It is the high-level oak of the western Himalaya, often ascending to the upper limit of tree growth except in places where the silver birch (*Betula utilis*) occurs above it. It descends occasionally to 6,500 ft., but is seldom found in abundance below 8,000 ft. Within its well-marked zone it is typically gregarious, forming pure forests along the tops and upper slopes of ridges. In Fig. 350 a belt of this oak is seen along the ridge in the foreground, and the far ridges are for the most part capped with it. It is frequently mixed with spruce (*Picea Morinda*), silver fir (*Abies Pindrow* or *A. Webbiana*), or yew (*Taxus baccata*), and in some localities with blue pine (*Pinus excelsa*). Among broad-leaved species occasionally associated with it are *Pyrus lanata*, *Prunus Padus*, *Acer caesium*, *Juglans regia*, and at the higher elevations *Betula utilis*. It is found both on deep rich moist soil in more or less sheltered localities and on poor rocky ground on the crests of ridges, where, however, it is usually stunted.

There is often a luxuriant herbaceous and shrubby undergrowth in the kharshu oak forests. Among the commoner shrubs are *Rosa macrophylla*, *Rubus niveus*, and other species, *Salix elegans*, *Viburnum stellulatum*, *V. cotinifolium*, *V. foetens*, *Lonicera angustifolia*, and the dwarf bamboo *Arundinaria spathiflora*. In some localities *Strobilanthes Wallichii* forms a dense soil-covering.

The kharshu oak forests occur in regions of heavy snowfall and at least moderate rainfall ; they do not extend into the driest parts of the inner Himalaya.

A typical but somewhat open crop of kharshu oak of first-class quality is shown in Fig. 351. This crop is in the Mohna block, Deoban, near Chakrata, at an elevation of 9,000 ft., on a north-easterly aspect ; the underlying rock is limestone and the soil is deep and rich. An enumeration on a representative 1-acre plot showed 54 trees, of which 24 were 1 to 5 ft. in girth, and 30 were 5 to 9 ft. in girth. The mean height was 79 ft. and the mean girth 5 ft. 9 in. The crop had been heavily opened out some years previously, and the density was little more than one-half, indicating that a fully stocked crop of this type

¹ Journ. For. School Tour, 1888.

² *Ibid.*, 1898–9.

³ Jubal State Working Plan, 1905.

would contain about 100 trees per acre. The young crops frequently grow up in extremely dense thickets.

LEAF-SHEDDING, FLOWERING, AND FRUITING. At the lower elevations the new shoots first appear early in May, and by the end of June the new leaves are fully developed and the shoots have almost attained full length; at the higher elevations the new shoots do not commence to appear until June. As a rule the old leaves begin to fall in May-June, and do not all fall until the new leaves are well out; sometimes, however, most of them fall before the new leaves are fully developed, and the trees are somewhat bare for a short time. The new shoots are tender, green, covered with a whitish tomentum, the previous year's shoots being greenish brown, shining, and lenticellate. The new leaves, subtended by brown deciduous stipules, are bright green above, with a felty light brown, nearly white, tomentum beneath; the old leaves are dark green above, turning brown before falling, with a brown tomentum beneath (Fig. 353, *a*).

The male catkins and female spikes appear with the new shoots, the former ripening and pollination taking place in the end of May or in June. The male catkins (Fig. 353, *a*, 1), 2-5 in. long or more, are found in sparse or dense pendulous clusters at the base of the new shoots, or a few are distributed singly along the lower parts of these shoots. The female spikes (Fig. 353, *a*, 2), up to 0.8 in. long, with 3-12 small sessile flowers, are axillary in the upper part of the new shoots; the flowers have three, sometimes four, recurved styles.

There is little or no growth in the young acorns until the following spring, when they commence growing rapidly as soon as the new shoots begin to appear, and by June they may be of any size up to 1 in. in diameter or even more; their growth is very uneven, a single spike at this time often containing young acorns of all sizes from about 0.3 in. in diameter upwards. These young acorns occur solitary or in pairs, or in clusters of 3-6 or more (Fig. 353, *a*, 3, and *b*). Their colour is dark green, intermingled with rich reddish brown, the base within the cup being pale greenish yellow; the cup is soft and leathery, the scales green with reddish brown tips.

The acorns (Figs. 353, *c*, and 354, *a*) commence ripening towards the end of June, and continue ripening during July, and at the higher elevations even into August; the period between the pollination of the female flower and the ripening of the acorn is therefore about thirteen months.

The ripe nuts are globose, inserted in a shallow grey leathery cup formed of small imbricate pointed scales, and vary much in size and colour. They average about 0.8-1 in. in diameter, and about 60 weigh 1 lb. Many fall green, turning brown on the ground, while others turn dark brown before falling. The nuts fall as soon as they ripen and germinate immediately, some even showing signs of germination before falling. Many have insect holes through them, but this does not prevent germination if the embryo is uninjured. The acorns are eagerly devoured by bears, langur monkeys, squirrels, and birds, but in a good seed-year they are produced in great abundance, and there is no lack of seed. Records of seeding are available for twelve consecutive years in Jaunsar; during this period good to abundant seeding was recorded in four years, and poor to moderate seeding in eight years.



FIG. 354. *Quercus semecarpifolia* SLEDING $\times \frac{1}{2}$

a—Acorn b-f— Germination stages g, h Development of seedling during first season

The seeds retain their vitality for a very short time, but the percentage of fertility of fresh seed is high. Tests showed a fertility of 95 to 100 per cent. I carefully examined a quantity of fallen acorns in the Jaunsar forests in the middle of July 1912; 90 per cent. had germinated, and of the remaining 10 per cent. about half were bad and the remainder were good but had not commenced germination.

Occasionally 2- to 4-seeded acorns are found, a corresponding number of taproots emerging from a single acorn.

GERMINATION (Fig. 354, b-f). Hypogeous. Germination commences with the emergence of the radicle from the apex of the nut. Elongation quickly takes place of what appears to be the young taproot, but what consists in reality of two parts, (1) the cotyledonary petioles united into a tube, and (2) the young taproot at the base of and in continuation of this tube. If the petiolar tube be cut through longitudinally the minute plumule will be found at its junction with the taproot, and completely enclosed within the tube. The elongation of the petiolar tube continues until the young taproot is safely conveyed into the soil; the tube may thus attain a length of as much as 4 in. or even more. From this stage onwards the taproot elongates and thickens considerably, sending out numerous fibrous lateral rootlets. Meanwhile the petiolar tube splits near its base, and through the opening formed the young shoot emerges and ascends; sometimes more than one shoot emerges.

Germination under natural conditions takes place early in the rainy season when a thick growth of new grass or other herbaceous plants, in addition to dead leaves, covers the ground. Thus the object of this abnormal elongation of the cotyledonary petioles, in this case in the form of a tube, is evidently to transfer the embryo seedling, with its delicate young taproot, as rapidly as possible through this soil-covering, and to enable it to establish a connexion with the soil. This accomplished, the seedling continues for some time to receive nutriment from the fleshy cotyledons through their petiolar tube, and the remains of the cotyledons and of their long petiolar tube may still be found during the second season.

This abnormal elongation of the cotyledonary petioles is seen also in the case of *Shorea robusta*, where, however, the petioles are not united into a tube. The seed of both species is quickly perishable, and this may account for the special means necessary for bringing the germinating seedling quickly into contact with the soil. The tubular form of the cotyledonary petioles in the case of *Quercus semecarpifolia* is no doubt a protective device for guarding the plumule from injury.

THE SEEDLING (Fig. 354).

Roots: primary root long, terete, very thick in upper part, tapering rapidly downwards, brown, woody, rough and striate by cracking of the epidermis, younger parts minutely tomentose; lateral roots numerous, moderately long, fibrous, minutely tomentose, distributed down main root. **Hypocotyl** hardly distinguishable, subterranean. **Cotyledons** subterranean. Petioles united in a terete slightly arched tube 1-4 in. or more in length, which completely encloses the plumule and splits near the base to allow the young shoot to emerge; petiolar tube stiff, becoming somewhat woody, tomentose. Lamina 0.8-1 in. in diameter, thick, fleshy, outer surface rounded and much wrinkled, inner surface irregularly wavy and depressed, the two

cotyledons in close contact, base produced into a rough thick point behind the petiole. *Stem* erect or somewhat straggling, grooved, wiry, pale green or reddish, tomentose; internodes 0.3–1 in. long. *Leaves* simple, alternate. Stipules 0.1–0.2 in. long, linear acuminate, tomentose, pale green when young, turning dark brown, deciduous. Petiole 0.1 in. long, tomentose. Lamina 1.5–2 in. by 0.8–1.2 in., elliptical or oblong, spinous dentate, apex obtuse, mucronate, base rounded or cordate, sub-coriaceous, pubescent on both surfaces with a tomentose fringe round the margin.

Under natural conditions the seedling as a rule produces in the first season nothing more than a small leafless stem 2 to 3 in. high, on which normal foliage leaves are replaced by mere scales with buds in their axils, and normal leaves are produced for the first time only in the second season; under favourable conditions, however, normal leaves are produced during the first season, as shown in Fig. 354. Although the development of the stem is small the taproot grows rapidly in length and thickness, enabling the seedling to establish itself successfully. Many seedlings die down towards the end of the first season and often for a few years subsequently, sending up new and stronger shoots each year from dormant collum buds until they finally commence upward growth; only under favourable conditions do they grow steadily from the commencement without dying back. The leafless form of the first season's shoot is an interesting adaptation for withstanding the climatic rigours at the high elevations at which this oak grows. The growing season is a short one, and is followed by a period of autumn drought and a severe winter; after germination the young plant therefore at once assumes a leafless winter form in preparation for the adverse conditions with which it has to contend. It may be noted that when young plants are artificially grown below their natural elevation and are specially tended they produce normal foliage leaves in the first season and do not die back. The rate of growth of seedlings is very slow, averaging only about 2 to 4 in. a year in height in the case of those grown under natural conditions, though the growth is somewhat faster in the case of plants raised in the nursery.

SILVICULTURAL CHARACTERS. This oak is a light-demander, and fails to establish itself under shade which is at all heavy (see under 'natural reproduction', below). It coppices and pollards fairly well, though coppice and pollard shoots are liable to be bent or broken by snow; the latter in particular are so liable to snow-break that pollarding is not a system to be recommended. Coppiced stools often send up a large number of shoots, of which a few eventually survive and suppress the remainder. The growth of coppice-shoots is slow. What appears to be natural coppice is sometimes met with; this is known to be due in some cases to fire. The leaves, particularly when young, are readily eaten by goats and sheep. The root-system of this oak is massive, and the tree is not so liable to be thrown by wind as *Q. dilatata*, although in exposed situations windfalls are occasionally met with. It grows in the region of heavy snow, and sometimes suffers from snow-break, particularly in dense pole crops. Regular thinnings should tend to minimize this damage. At the higher levels the trees not only have their branches broken by the masses of snow which accumulate on the crowns during the winter, but are also uprooted and piled up in heaps by sliding snow.

NATURAL REPRODUCTION. Under natural conditions germination, as



FIG. 355. *Quercus lanuginosa* FLOWERS AND FRUIT $\times \frac{1}{2}$

a—Young shoot, April - May, with male catkins (1) and female spikes (2) b Young acorns, half grown, about five months old, end of September c Ripe acorns, end of December

already noted, takes place as soon as the seed falls, between June and August, that is, early in the rainy season. Conditions for germination therefore are good, since the seed does not lie exposed to the attacks of animals, and the young seedling obtains the full benefit of the rainy season in which to push its long taproot down into the soil and to become established. After a good seed-year young seedlings may be found in large quantities. In 1909 I demarcated a plot of natural seedlings 22 ft. square, that is, 53·8 square yds. in area, in the Mohna block at Deoban in Jaunsar. The seedlings were chiefly under 1 ft. in height, but a few were more, the maximum height being 2 ft. 3 in. The seedlings in this plot were carefully counted that year and for five years subsequently, with the following result :

Quercus semecarpifolia : enumeration of natural seedlings in demarcated plot.

year.	Number of seedlings in plot.	Equivalent number. per square		Height of largest seedlings.
		yard.	per acre.	
1909	651	12·1	58,590	27 in. (maximum).
1910	1,320	24·5	118,800	
1911	1,560	29·0	140,400	
1912	2,441	45·4	219,690	36 in. (maximum), 35 in., 34 in., 33 in., 32 in., 31 in.
1913	2,392	44·5	215,280	38 in. (maximum), 37 in., 36½ in., 36½ in., 36 in., 36 in.
1914	1,687	31·4	151,830	39 in., 39 in. (maximum), 38 in.

These figures indicate the profusion with which natural seedlings are capable of springing up, and they also demonstrate the extremely slow growth of even the most vigorous of them. The marked increase in the number of seedlings between 1909 and 1912 was due mainly to fresh germination ; it is quite possible, however, that many seedlings may have escaped notice for one year owing to their leafless stems or owing possibly to their having died back. The decrease in the number after 1912 was apparently due to the suppression of the smaller and less vigorous seedlings.

For the establishment of natural reproduction abundant overhead light is essential, and if this is ensured and the other conditions are favourable, thickets of great density establish themselves in the neighbourhood of seed-bearers. Frequently along the edge of an oak wood a mass of sapling reproduction resembling a thick hedge springs up, while in the interior of the wood nothing beyond the seedling stage is to be found. Similarly where the canopy of an oak wood has been heavily opened out dense thickets of young oak appear in the gaps. Fig. 352 gives some idea of this. Where trees are standing in the open there are often dense thickets of young growth on the downhill side of them, and it is noticeable how isolated seed-bearers crowning a ridge will produce such thickets extending for some distance down the slopes on either side.

Heavy grazing prevents oak reproduction, but instances have been observed where light grazing has not had any appreciable effect on its establishment. Natural reproduction is often prevented from establishing itself by a dense growth of weeds and heavy undergrowth, particularly in moist depressions. Among the most troublesome weeds is *Strobilanthes*

Wallichii, which produces a dense matted growth preventing oak reproduction. This plant, an account of which is given in Vol. II, pp. 695-6, flowers and dies at intervals of twelve years. In Jaunsar numerous oak seedlings have been observed to establish themselves immediately after the periodic flowering. Experiments have also shown that the *Strobilanthes* can be eradicated successfully by cutting it down in the year of flowering immediately before the ripening of the fruit, that is in September; this eradication has been found to result in the establishment of many oak seedlings which could not otherwise have survived.

On the upper slopes of China hill at Naini Tal, where this oak occurs naturally, reproduction persistently fails, but the cause of this has not yet been ascertained.

ARTIFICIAL REPRODUCTION. This oak has on several occasions been raised successfully in Jaunsar by sowing in contour lines or by dibbling. It is necessary to have the contour lines prepared in advance and to sow the seed as soon as it ripens; fairly open places should be chosen. Transplanting from the nursery was also carried out at one time in Jaunsar, but no details are available, direct sowing having been more usual.

SILVICULTURAL TREATMENT. The kharshu oak is sometimes worked as coppice, but this system is not always satisfactory as the coppice-shoots are liable to be bent or broken by snow: their growth, too, is very slow. From what has already been noted under 'natural reproduction' it will be seen that this oak is well adapted for working as high forest under the system of successive regeneration fellings, a somewhat open seeding felling being made, followed by a further opening of the canopy as soon as natural reproduction begins to appear in the gaps. A heavy opening of the canopy several years ago in the Mohna block, Jaunsar, was followed by promising masses of reproduction wherever there was sufficient light and the growth of weeds was not too heavy; owing to the slow growth of the seedlings, however, it was a long time before there were any visible results. Judging from the tendency of the oak to regenerate in fringes in the open along the edges of the woods, clear fellings in narrow strips would probably give good results. Owing to the density of the young crops thinnings should be commenced in the thicket or young pole stage.

RATE OF GROWTH. (1) *Coppice.* Periodical measurements in coppice coupes near Deoban in Jaunsar show the following mean rate of growth:

Quercus semecarpifolia: rate of growth of coppice, Jaunsar.

Age. years.	Mean girth. in.	Mean height. ft.
5	3.0	3.7
10	4.9	6.5
15	6.3	9.2
20	7.7	11.7
25	9.0	14.0
30	10.0	16.2
35	11.0	18.4

(2) *High forest.* Periodical measurements in young plantations in Jaunsar gave the following results:

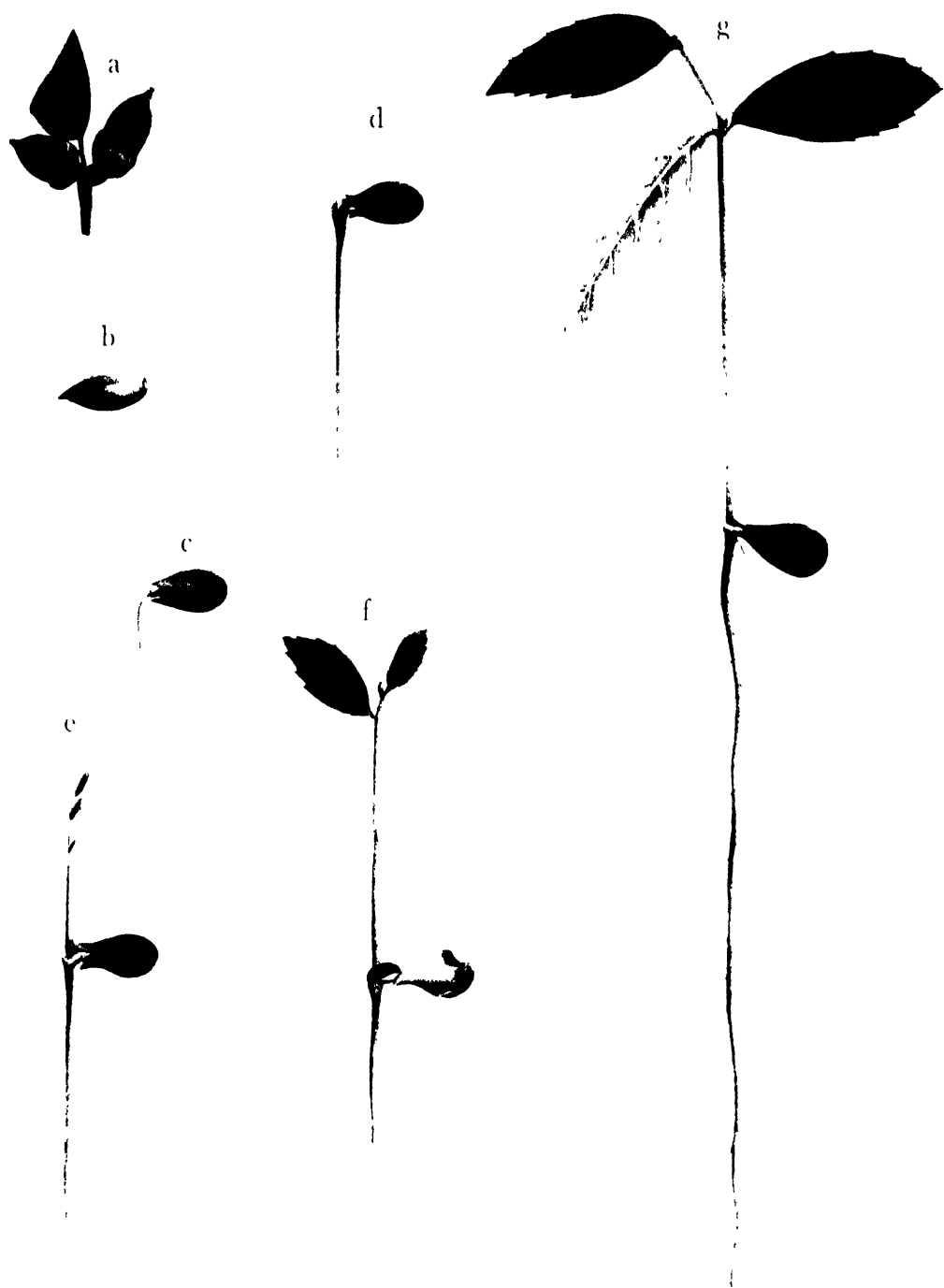


FIG. 356. *Quercus lanuginosa*—SEEDLING $\times \frac{1}{4}$

a—Acorns b Nut of acorn c - e Germination stages f, g.—Development of seedling during first season

Quercus semecarpifolia : rate of growth in young plantations, Jaunsar.

Age (from seed).	Mean girth.	Mean height.
years.	in.	ft.
5	1.4	1.8
10	2.7	3.7
15	4.2	5.5
20	5.6	7.3

The rate of growth in girth, deduced from measurements in four Research Institute sample plots, in natural crops at Deoban in Jaunsar, of which two were thinned and two were not thinned, is as follows : ¹

Quercus semecarpifolia : rate of growth in girth in natural crops, Jaunsar.

Mean girth.			Mean girth.		
Age.	Thinned plots.	Unthinned plots.	Age.	Thinned plots.	Unthinned plots.
years.	ft. in.	ft. in.	years.	ft. in.	ft. in.
10	0 2½	0 1½	70	2 2½	1 8
20	0 5½	0 4½	80	2 7½	1 11½
30	0 9½	0 7½	90	3 1½	2 3
40	1 2	0 10½	100	3 7½	2 6½
50	1 6	1 1	110	..	2 10½
60	1 10	1 4½	120	..	3 3

These results are based on measurements for one quinquennial period only, and are therefore only tentative.

The Jaunsar working plan of 1901 gives the following estimated rate of growth, based on ring-countings : ²

Quercus semecarpifolia : rate of growth, Jaunsar.

Age.	Mean girth.	Mean height.
years.	ft. in.	ft.
20	..	5
40	0 8	15
60	1 7	24
80	2 3	33
100	2 11	43
120	3 7	54
140	4 4	65
160	5 0	76

4. *Quercus lanuginosa*, Don. Woolly oak. Vern. *Rianj*, Kumaun ; *Banga*, Nep.

A large evergreen tree, somewhat resembling *Quercus incana*, but the leaves are broader and densely whitish to rusty tomentose on the lower surface, while the young shoots are more woolly. Bark grey, either smooth and shining, with numerous small lenticellate excrescences and exfoliating in rather large irregular sheets, or rough by exfoliation in numerous rectangular scales of smaller size. On old trees the bark often forms horizontal raised rings at intervals up the bole. Wood very hard, used as fuel along with other associate oaks.

In the open the tree tends to branch low and to form a short bole, but when grown in a close crop a straight clean bole is formed. I have measured trees up to 70 ft. in height and 11 ft. in girth.

¹ Statistics compiled in the Silviculturist's Office, 1916-17, Ind. For. Rec., vol. vi, pt. v, 1918.

² Working Plan for the Jaunsar-Bawar Forests, P. H. Clutterbuck, 1901. (Girth measurements converted from diameter measurements recorded in the plan.)

DISTRIBUTION AND HABITAT. The distribution of this tree is very local. It occurs in patches, sometimes of small extent, in the Garhwal and Kumaun Himalaya, extending eastward to Bhutan, at 4,000–8,000 ft. Mr. Jacob¹ says that in Bhutan it occurs chiefly in the inner valleys with *Quercus Griffithii* at 6,000–8,000 ft. Mr. A. E. Osmaston informs me that he found a gregarious patch about 30 to 40 acres in extent, containing some large trees, in the Divadanda block in Garhwal. There are some patches in the hills of the Naini Tal district at elevations of 6,000 to 7,500 ft. In this district it is perhaps commonest round Kilberry, where it is found on limestone and shale, and may be seen clinging to limestone rocks on precipitous ground. It is associated with *Quercus incana* and *Rhododendron arboreum*, and at its upper and lower elevations with *Quercus dilatata* and *Pinus longifolia* respectively. The tree is typically gregarious, often occurring in dense pure patches (Fig. 357). It may be found along the tops of shaly ridges on poor soil, but in such places it is stunted. It is often found on sunny slopes. In the Naini Tal hills *Quercus dilatata* is tending to supplant it in cool sheltered places.

In those parts of the Naini Tal hills where this oak occurs the rainfall is about 90 in.; the absolute maximum shade temperature is probably slightly over 90° F., and the absolute minimum is between 20° and 25° F.

Seedlings recently planted in the Forest Research Institute grounds at Dehra Dun promise well.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The young shoots appear in March or early April; they are covered with a dense woolly tomentum of a pale tawny or rusty colour which persists throughout the season, becoming a dirty grey colour by the end of the year, but disappears in the second season, the shoots becoming dark grey or brown. The young leaves (Fig. 355, *a*), subtended by downy brown deciduous stipules, are woolly tomentose on both surfaces, but the tomentum soon disappears from the upper surface, which becomes dark green, glabrous, and shining, with a yellow midrib (Fig. 355, *b*). The time of shedding of the old leaves has not been accurately recorded, but they have been observed to be still on the trees in October.

The male catkins and the female spikes appear with the young shoots, the former maturing and pollination taking place towards the end of April and during May. The male catkins (Fig. 355, *a*, 1), arranged in pendulous clusters at the base of the young shoots or singly along the lower part of those shoots, are usually 4–8 in. long, but have been measured up to 14 in. in length, the flowers in this case being widely separated. The female spikes (Fig. 355, *a*, 2) are axillary in the upper parts of the new shoots; the flowers, usually 2–5 in number, sometimes more, are sessile on the common peduncle, the woolly tomentum on which almost hides them.

After pollination the young acorns commence to develop, and by September are usually about 0.2–0.5 in. long by 0.2–0.4 in. in diameter, the nuts for the most part well out of the cup, green with a thick covering of short light grey woolly hairs (Fig. 355, *b*). From then onwards they grow rapidly, and ripen in the latter half of December and in January, that is, about eight months from the time the female flower is pollinated. They fall to the ground by degrees from the time of ripening onwards.

¹ Report on the Forests of Bhutan, 1912.



FIG. 357. *Quercus lanuginosa*, pole crop. Kumaun hills.

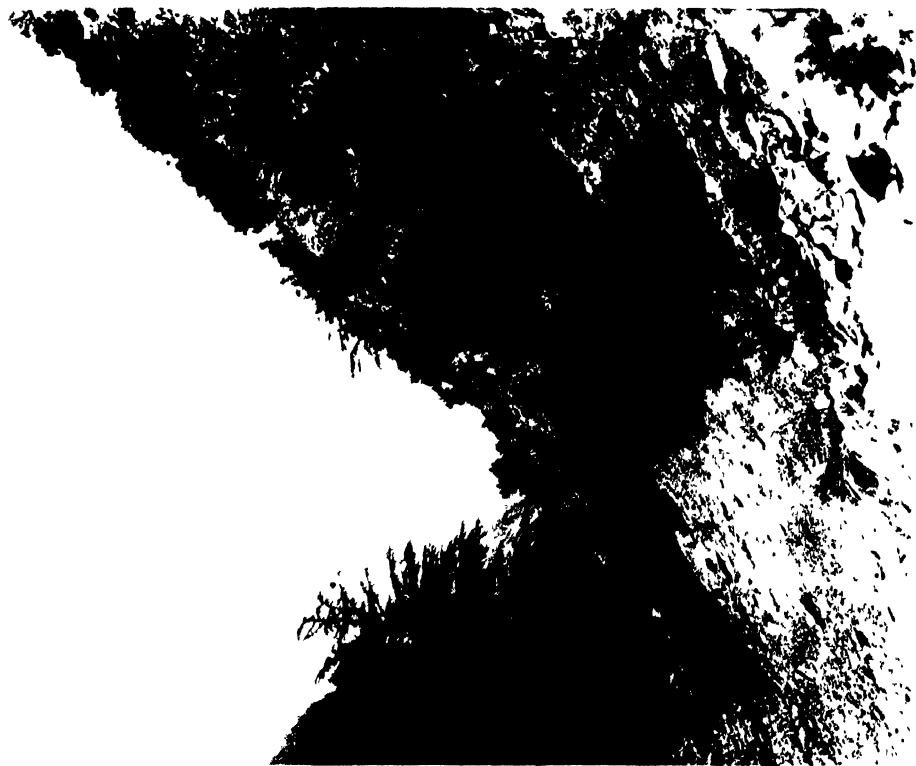


FIG. 358. *Quercus Ilce* growing gregariously on a dry rocky slope at 5 000 ft., Kagan valley, Hazara. *Cedrus Deodara* on left.

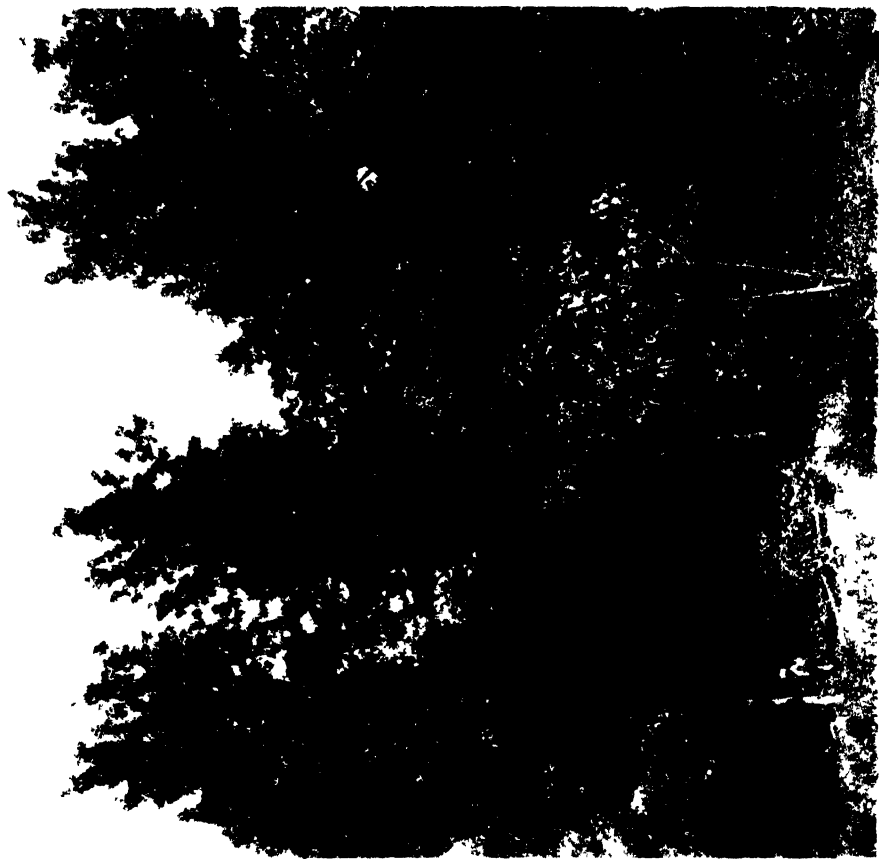


FIG. 359. *Quercus sonata*, plantation 30 years old, Kaunli, Dehra Dun.

The acorns (Figs. 355, *c*, and 356, *a*) are sessile, usually in clusters of 2-5. The cup is 0.4-0.5 in. in diameter, with closely adpressed woolly tomentose imbricate scales, shallow, enclosing the nut for less than one-quarter of its length to nearly one-half. Nut (Fig. 356, *b*), 0.5-0.7 in. long by 0.3-0.45 in. in diameter, ovoid, light brown, smooth, shining, covered with light grey, woolly hairs for some distance from the apex.

The acorns are eagerly devoured by bears, and, as in the case of most Himalayan oaks, are much subject to the attacks of boring caterpillars.

GERMINATION (Fig. 356, *c-e*). Hypogeous. The shell of the nut splits towards the apex and the radicle emerges, descending rapidly and forming a taproot. Meanwhile the cotyledonary petioles elongate to about 0.1-0.2 in., enabling the plumule to emerge and the young shoot to ascend. The fleshy cotyledons remain within the shell on or under the ground; they remain attached for some time to the young plant, supplying it with nutriment in its earlier stages.

THE SEEDLING (Fig. 356).

Roots: primary root long, fairly stout, terete, tapering, wiry, tomentose; lateral roots fairly numerous, moderately long, fibrous, distributed down main root. *Hypocotyl* more or less distinct from root, 0.1 in. long or less, thick, tomentose, subterranean. *Cotyledons* subterranean. Petiole 0.1-0.2 in. long, flattened, tomentose. Lamina 0.4-0.6 in. by 0.25-0.4 in., thick, fleshy, apex rounded, base prolonged behind petiole, outer surface convex, inner flattened in contact. *Stem* erect, terete, woody, woolly tomentose; internodes 0.2-2.5 in. *Leaves*, first pair usually abortive, opposite, sub-opposite or alternate, subsequent leaves normal, alternate or sometimes sub-opposite. Stipules 0.1 in. long, linear falcate. Petiole 0.1 in. long, or less, woolly tomentose. Lamina 1.2-3 in. by 0.6-1.5 in., elliptical ovate, acute, serrate, woolly tomentose.

The growth of the seedling is slow. By the end of the first season a height of 2 to 5 in., with two to four leaves, is ordinarily attained, and subsequent growth is at the rate of only a few inches a year. Seedlings raised at Dehra Dun attained an average height of 1 ft. 7 in. in four years.

SILVICULTURAL CHARACTERS. This oak is more light-demanding, but less exacting as to soil and exposure, than *Quercus dilatata*. It coppices well. It has a massive root-system, and appears to be wind-firm.

NATURAL REPRODUCTION. Under natural conditions the seed lies on the ground during a portion or the whole of the hot season, and germinates during the rainy season. This oak appears to resemble *Quercus incana* so far as conditions for successful natural reproduction are concerned, but if anything reproduction seems to be capable of establishing itself on somewhat drier localities than in the case of *Q. incana*. Natural seedlings are found most plentifully on open grassy slopes and spurs, often along with seedlings of *Pinus longifolia*. In sheltered localities in the Naini Tal hills, seedlings of *Quercus dilatata* may sometimes be found springing up in quantity under an overwood of *Q. lanuginosa*, indicating that the former species is tending to supplant the latter in such places.

ARTIFICIAL REPRODUCTION. Experiments at Dehra Dun have shown that this oak can be grown successfully either by direct sowing or by transplanting from the nursery as in the case of *Quercus incana*. Care is necessary not to expose the roots too much during transplanting.

RATE OF GROWTH. Measurements of four trees in a mixed unthinned oak sample plot at Kilberry near Naini Tal showed an average girth increment of 2.8 in. in four years, or 0.7 in. in a year. Measurements of one tree in a thinned sample plot in the same locality showed a mean annual girth increment for the period of 1.2 in., which indicates that in thinned crops the growth may be fairly fast. The trees in question varied from 15 to 25 in. in girth at the first measurement.

5. *Quercus Ilex*, Linn. Syn. *Q. Baloot*, Griff. Holm oak. Vern. *Balút*, *charrei*, Afg.; *Pargái*, *kharanja*, trans-Indus; *Banj*, Chitral; *Chúr*, *bré*, *irri*, Pb.

A small or moderate-sized evergreen tree, often little more than a shrub. Leaves coriaceous, upper surface dark green, lower surface softly whitish or greyish tomentose, very variable in size and shape, 1–3 in. long, elliptical or oblong, entire or with large spinescent teeth, both forms sometimes on the same branch. Bark dark grey, divided into small scaly plates. Wood very hard, used in India for agricultural implements and tool-handles and much cut for fuel. The branches are lopped for cattle fodder. In Europe the bark is considered a good tanning material.

In the Himalayan region the tree sometimes reaches 5–6 ft. in girth, but is often kept in the condition of scrub by cutting and lopping. In the Kurram valley, Mr. Bagshawe measured eight trees averaging 7 ft. 1 in. in girth.

DISTRIBUTION AND HABITAT. This tree has a wide distribution, occurring in different soils and climates and showing considerable variation in different localities. It extends westward to southern France, Spain, and Portugal, often occurring in arid situations and on dry hill-sides. It is widely distributed in the Mediterranean region, from France and Spain eastward through Italy, the southern Tyrol, Corsica, Sicily, Greece, the coast region of Syria, and in other Mediterranean countries including Morocco, Algeria, and Tunis. It is often cultivated in England, where it reaches large dimensions.

In the Indian region it is found in the inner arid tracts of the Himalaya from the Sutlej valley, westward to Afghanistan. It is common on the eastern slopes of the Suliman range at 5,000–6,000 ft., in the Kurram valley at 6,500–9,000 ft., in the hills north of the Peshawar valley at 3,500 ft., in Chitral at 6,000–8,500 ft., and in the arid valleys of the upper Jhelum, Chenab, Ravi, and Sutlej at 4,000–8,500 ft. In the Kagan valley it is common and gregarious at 4,500–6,000 ft., usually associated with *Fraxinus xanthoxyloides* and *Daphne oleoides*, and in places with deodar (see Fig. 358). In Kashmir it is common on the hot southerly slopes in the lower part of the valley of the Kishanganga and its two tributaries, the Karna and the Jagran, at 3,500–7,000 ft.

In the dry regions which it frequents it is often found associated with *Pinus Gerardiana*, growing on dry, rocky, hot slopes. In Chitral it is a common companion of the deodar, especially at the lower elevations of the latter, and is sometimes associated with the blue pine.¹

LEAF-SHEDDING, FLOWERING, AND FRUITING. In England the leaves persist for two or three years (Henry); in India they persist as a rule for less than 1½ years. The following remarks apply to trees in the Indian region:

The young shoots, which are covered with a pale grey stellate pubescence,

¹ Report on the Chitral Forests, Imam-ud-din, 1908.



FIG. 360. *Quercus ilex* FLOWERS AND FRUIT $\times \frac{7}{8}$

- a—Male catkins, April, May b.—New shoot and portion of previous year's shoot, with female flowers
 at time of pollination (1) and young acorns one year older (2) , April, May
 c—Ripe acorns, October of second season

appear in March–April (Fig. 360); the young leaves on the under side are pale grey stellate tomentose, on the upper side pubescent with stellate hairs, afterwards becoming glabrate. The male catkins (Fig. 360, *a*), in drooping clusters, up to 3 in. long, appear at the base of the new shoots and ripen in April–May, when pollination takes place. The minute female flowers (Fig. 360, *b*, 1), usually two or three, are sessile on slender peduncles up to 1.5 in. long, axillary on the upper part of the new shoots.

There is little or no growth in the young acorns during the first season, and they remain small until April–May of the second season (Fig. 360, *b*, 2), after which the acorns develop rapidly. By the end of June they are about 0.3 in. in diameter, with the nut completely enclosed in the cup of imbricate pale greyish green scales. The acorns (Fig. 360, *c*) ripen about October, and are usually two or three in number on a common peduncle. The nuts are 0.8–1.2 in. long by 0.4–0.6 in. in diameter, oblong conical, light brown, glabrous, shining; the woody cup is greyish brown with closely adpressed scales, and encloses about one-quarter to one-third of the nut.

In the Himalayan region a period of about a year and a half thus elapses from the time of pollination of the female flower until the ripening of the acorn.

SILVICULTURAL CHARACTERS. This is a typically xerophytic species, often forming low scrubby growth with spinous leaves and growing on dry stony or rocky ground and hot slopes. Its xerophytic habit is further exhibited by its capacity for producing root-suckers, unlike most oaks, especially when the stumps of felled trees are dug out or split, as is done in Provence to stimulate reproduction by suckers. The tree coppices well, and in the Mediterranean region is frequently worked as coppice for the production of tanning bark.

RATE OF GROWTH. According to Gamble the growth is slow and the rings uncertain. Ring-countings by Mr. Bagshawe on the eight trees in the Kurram valley referred to above gave an average of 270 rings for a mean girth of 7 ft. 1 in. or a mean annual girth increment of 0.31 in. Khan Bahadur Imam-ud-din estimated the rate of growth of coppice-shoots in Chitral at about 10 in. in height per annum.

6. *Quercus serrata*, Thunb.

A moderate-sized or large handsome deciduous tree, forming a full rounded crown when grown in the open and a straight clean bole when grown in a close crop. Leaves lanceolate or elliptical lanceolate, 5–7 in. long, sharply serrate, glabrous when mature and green on both sides. Bark dark greyish brown, rough, with deep irregular vertical fissures. Wood very hard, dark greyish brown, used for building. A fast-growing tree suitable for plantations and for ornamental and shade purposes. It reaches fairly large dimensions. A tree about 7 ft. in girth was recently felled at Dehra Dun, where also there is a cross-section 8 ft. 1½ in. in girth in the silvicultural museum.

DISTRIBUTION. Eastern Himalaya at 3,000–8,000 ft., Khasi hills, Manipur, hills of Upper Burma at 3,500 ft. and over, China, and Japan. This is one of the common oaks at Maymyo, where it occurs at 3,500 ft. with *Quercus Griffithii*, *Schima Wallichii*, *Castanopsis*, and various other trees, with an undergrowth often consisting of bracken. Here it is most common on the more fertile soils,

particularly on red clayey loam, and often becomes gregarious in moist situations. In the Chin hills it is common along with *Pinus Khasya*, *Rhododendron arboreum*, *Alnus nepalensis*, and other oaks. It has been much planted in the cinchona plantations of the Darjeeling hills. It grows well at Dehra Dun, where it has been planted for ornament; there is a small plantation of it in the Kaunli garden at that place (Fig. 359).

LEAF-SHEDDING, FLOWERING, AND FRUITING. The dates given here refer to Dehra Dun only. The leaves turn yellow and brown and commence falling in November, and by January the trees are leafless. The new delicate green leaves appear in February. The male catkins are first visible in October or early November, and are to be seen, up to about 1 in. in length, at the ends of the leafless branches in January; with the sprouting of the new shoots in February they elongate rapidly, attaining a length of 4–6 in. Pollination takes place in February or March. The small green 3-styled female flowers appear on the new shoots in February, and hardly develop for a whole year, remaining about 0.1 in. in diameter, and brown in colour, through the ensuing winter. In the second year they commence increasing in size in March and develop rapidly, ripening and falling in September and October. The acorn (Fig. 361, *a*) varies much in size. The nut is broadly ovoid to globose, 0.8–1.2 in. long by 0.6–1 in. in diameter, with an obtuse apex, brown, glabrous and shining; its base is enclosed about one-third to one-half in a woody cup with spreading recurved scales. About 70 to 120 nuts weigh 1 lb. Fertile seed commences to be produced fairly early. The trees in the plantation at Kaunli, Dehra Dun, produced fertile seed in abundance at twenty-two years of age. At Dehra Dun the immature seed-crop is sometimes destroyed by storms.

GERMINATION (Fig. 361, *b–e*). Hypogeous. The radicle emerges from the apex of the nut and descends rapidly, forming a long stout taproot. Meanwhile, the cotyledonary petioles elongate to about 0.3 in., enabling the plumule to emerge and the young shoot to ascend. The fleshy cotyledons remain within the nut on or under the ground; they remain attached to the young plant for a considerable time, supplying it with nutriment in its earlier stages.

THE SEEDLING (Fig. 361).

Roots: primary root long, thick, terete, tapering, brown, woody, longitudinally wrinkled; lateral roots numerous, moderately long, fibrous, distributed down main root. *Hypocotyl* fairly distinct, about 0.1 in. long, thick, subterranean. *Cotyledons* subterranean. *Petiole* 0.3 in. long, flattened. *Lamina* 0.8–1 in. by 0.6–0.7 in., thick, fleshy, obovate, apex more or less truncate, base slightly prolonged over the petiole, outer surface rounded, longitudinally wrinkled, inner flattened in contact. *Stem* erect, terete, green, tomentose; internodes in first season 0.4–1 in. long. *Leaves*, first pair opposite, sub-opposite or alternate, subsequent leaves alternate, first few leaves often scaly and rudimentary. *Stipules* 0.1–0.15 in. long, linear falcate, tomentose. *Petiole* 0.1 in. long. *Lamina* 1–2.8 in. by 0.4–0.7 in., oblong or elliptical lanceolate, acuminate, base rounded, sharply serrate, pubescent when young; lateral veins 8–12 pairs.

The growth of the seedling is fast. At Dehra Dun nursery plants kept weeded and watered attained by the end of the first season a height of 3 ft. 10 in., with a strong taproot 2 ft. 9 in. long. In the case of direct sowings, where

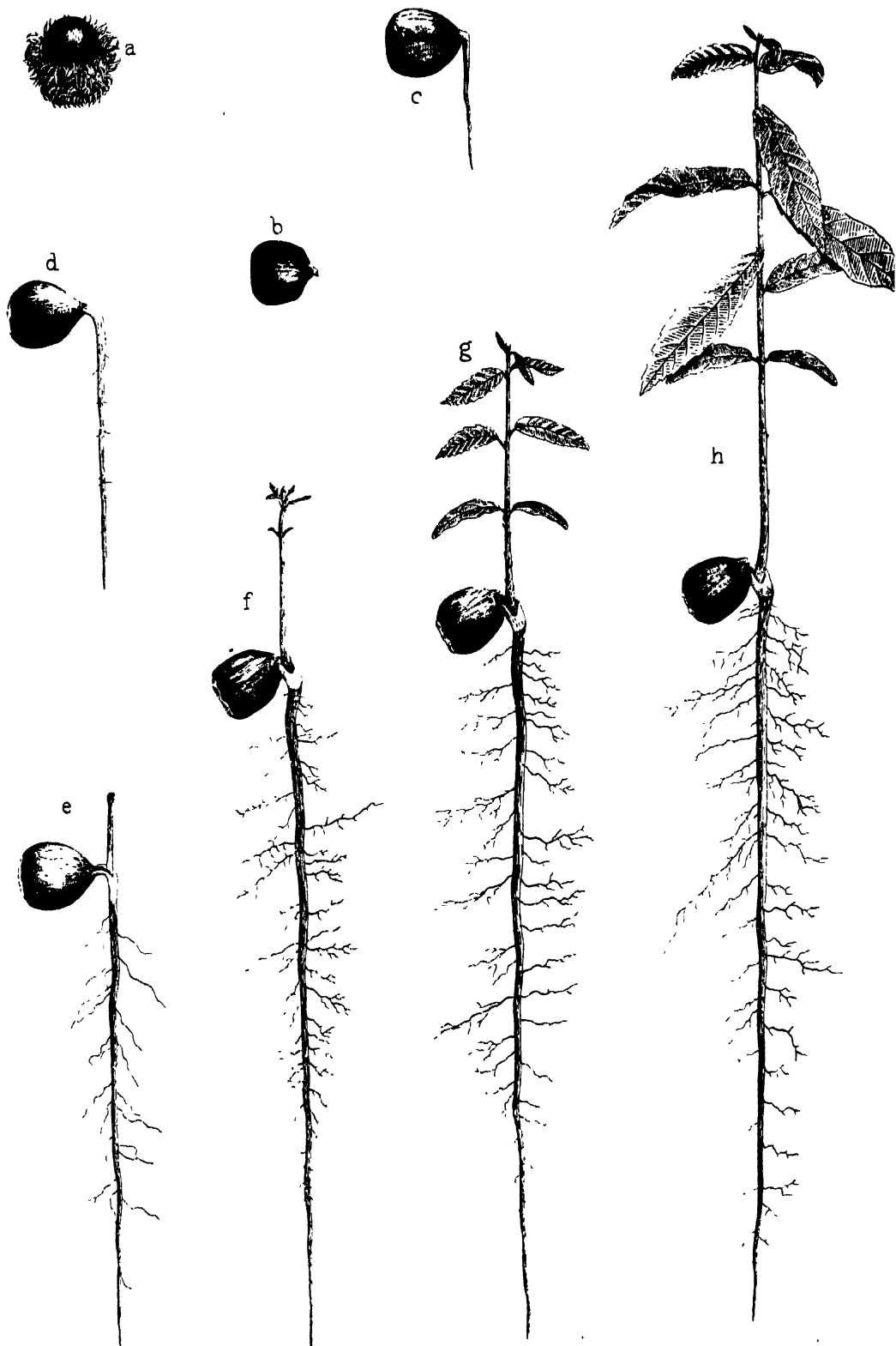


FIG. 361. *Quercus serrata*. Seedling $\times \frac{1}{2}$.
 a, acorn ; b-e, germination stages ; f-h, development of seedling to end of first season.

no weeding or watering was done, seedlings attained a height of 10 in. by the end of the first season and 4 ft. by the end of the second season. Transplants from the nursery reached a height of 7 to 7½ ft. in three years.

SILVICULTURAL CHARACTERS. This oak is a moderate light-demander, saplings establishing themselves readily in gaps, but not under cover which is at all heavy. At Dehra Dun it is frost-hardy. It coppices well up to a moderate size.

NATURAL REPRODUCTION. Experiments at Dehra Dun showed that seeds lying uncovered in the open tend to split, and fail to germinate, and that for successful germination under natural conditions they require either to become covered soon after falling or to lie shaded from the sun. In the Kaunli plantation natural seedlings appear in quantity under fairly dense shade, but these do not survive long except round the edges of the plantation where they have abundant light. In the Maymyo forests this oak regenerates freely in gaps and open spaces, where seedlings and saplings may often be found springing up in abundance.

ARTIFICIAL REPRODUCTION. For forest purposes direct sowing is usually preferable to transplanting, owing to the length of the taproot. Experiments at Dehra Dun, however, have shown that transplanting can be carried out quite successfully during the first rainy season by pruning down the taproot to a length of about 9 in. and cutting down the stem or stripping off the leaves; the seed should be sown in February, the beds being regularly watered and weeded, and by July or August the seedlings will have attained a height of 1–2 ft. with a taproot up to 2 ft. or more in length. The Kaunli plantation at Dehra Dun was formed in 1895 by transplants spaced 6 ft. by 6 ft. Successful results have been attained in the Maymyo fuel reserve by sowing in ploughed lines.

SILVICULTURAL TREATMENT. This oak is suitable for treatment under successive regeneration fellings, light being admitted early to the young crop; unregenerated gaps are easily filled up artificially by dibbling or by sowing in ploughed lines. Thinnings require to be commenced early, as the young crops are sometimes dense. The Kaunli plantation has suffered much from want of thinning.

RATE OF GROWTH. The growth under favourable conditions is rapid. A cross-section 8 ft. 1½ in. in girth in the silvicultural museum at Dehra Dun, cut from a tree grown in that place, had 45 annual rings, giving a mean annual girth increment of 2.17 in. The Kaunli plantation at an age of twenty-three years (from seed) had a mean girth of 23.6 in. and mean and maximum heights of 50 ft. and 69 ft. respectively; these measurements were made immediately after thinning. The plantation had not previously received attention in the way of thinning, otherwise the mean girth would probably have been greater. A thinning made at twenty-three years of age removed 673 stems per acre with a solid volume of 1,178 cubic ft., leaving 365 stems per acre with an estimated volume of 2,231 cubic ft.

7. *Quercus Griffithii*, Hook. f. Vern. *Dingim*, Khasi hills; *Mettein*, *thitcha*, Burm.

A large deciduous tree with coriaceous leaves 6–9 in. long, usually pubescent beneath. Wood very hard, of good quality. Bhutan, very common in the



FIG. 363 *Quercus glauca*—FLOWERS AND FRUIT $\times \frac{3}{4}$

- a Young shoot and leaves with male catkins (1) and female flowers (2), March-April
 b—Young acorns June c Half-grown acorn, August-September
 d Ripe acorn October-November, seven months after first appearance of female flower

inner valleys at 4,000–8,000 ft. from the Raidak valley eastwards (Jacob), Khasi and Naga hills, Manipur, hills of Burma east of the Irrawaddy and Sittang. A gregarious tree which, as Gamble remarks, deserves more attention owing to its excellent wood, which resembles that of *Q. Robur* of Europe. It has been successfully cultivated along with *Q. serrata* in the cinchona plantations near Darjeeling, and has shown fast growth.

This is one of the common oaks of Maymyo in Burma, where it grows at 3,500 ft. and upwards along with *Quercus serrata*, *Schima Wallichii*, *Castanopsis*, and many other trees, often with an undergrowth of bracken fern. It is a moderate light-demander, and regenerates freely in gaps and open spaces. At Maymyo it has been raised successfully by line sowings in blanks.

8. *Quercus glauca*, Thunb. Syn. *Q. annulata*, Smith. Vern. *Barin*, *báni*, *indí*, *phanát*, W. Him. ; *Phalat*, Nep. (Fig. 365.)

A handsome evergreen tree with a dense rounded crown and a clean, cylindrical, though not very long bole. Leaves 3–6 in. long, oblong or ovate-lanceolate, upper part serrate, base entire, green, glabrous above, glaucous beneath. Bark thin, grey, smooth. Wood very hard, not much used except for fuel. A handsome tree worth cultivating for shade and ornament in moist situations. In the western Himalaya I have never seen any trees of large size, the largest found being about 5 ft. in girth and 50 ft. in height.

DISTRIBUTION AND HABITAT. Generally distributed throughout the outer Himalaya, ascending to 6,000 ft., also in the Khasi hills. The tree is found typically in moist situations in valleys, on the sides of ravines and along streams. In the Kangra valley it occurs at 3,000 ft. near Shahpur, mixed with *Quercus incana* and associated with *Albizzia stipulata* and other low-level trees. It is not as a rule gregarious except along the banks of streams ; in moist localities in the western Himalaya it is often associated with *Machilus odoratissima* and other evergreen laurels, while *Quercus incana* is also one of its commonest companions. In the *Pinus longifolia* forests of the Kumaun hills it grows plentifully along some of the streams in the valleys, for example below Ranikhet. There is an interesting patch of forest between Baijnath and Dhelu in the Mandi state, at 4,000–5,000 ft. on a northerly aspect, where the rock is sandstone and shale, and the soil is a deep moist clayey loam ; here *Quercus glauca* forms the great bulk of the crop, and in places is almost pure, its chief associates being *Quercus incana*, with a little *Pinus longifolia*, *Rhododendron arboreum*, and *Pieris ovalifolia*. In the Beas valley in lower Kulu it occurs at 3,000 ft., associated with *Quercus incana*, *Pistacia integerrima*, *Pyrus Pashia*, *Olea cuspidata*, and other trees. In Hazara it occurs in moist ravines in the *Pinus longifolia* forests of Khanpur and Siran at 4,000–5,000 ft.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The new green shoots and the delicate copper-coloured young leaves, with fine silky hairs on the under surface and subtended by light brown deciduous stipules, appear in March or early April. The old leaves commence turning yellow and falling soon after the young shoots appear, but are not all shed until the new leaves are fully out. The male catkins and female flowers appear with the new shoots. The male catkins (Fig. 362, *a*, 1), 2–3 in. long, are in dense pendulous clusters at the base of the new shoots, and the female flowers (Fig. 362, *a*, 2), usually in twos or threes, are sessile on common axillary peduncles 0.25–0.5 in. in length

on the new shoots. After pollination the development of the young acorn is rapid. By the end of May or June the annulations are already distinct on the cup, which is 0.1–0.2 in. in diameter, and still encloses the nut (Fig. 362, *b*). The nut commences to protrude soon after, and by August or September the acorn is half grown but still green (Fig. 362, *c*). It ripens in October–November, that is in the short period of seven months from the time of first appearance of the female flower. The cup is shallow, greyish and annulate with several velvety belts of connate scales, and the nut (Fig. 363, *b*) is 0.6–0.9 in. long by 0.3–0.4 in. in diameter, pointed, light brown, smooth, shining and glabrous (Figs. 362, *d*, and 363, *a*). About 330–350 nuts weigh 1 lb. The nuts fall soon after ripening, separating readily from the shallow cups, which may remain for some months on the tree. The seed retains its vitality for some months at least; seed kept for eight months and tested at Dehra Dun showed a fertility of 90 per cent.

GERMINATION (Fig. 363, *c–e*). Hypogeous. The shell of the nut splits towards the apex and the radicle emerges, at once descending and forming a taproot. Meanwhile the cotyledonary petioles elongate to about 0.2–0.3 in., enabling the plumule to emerge and the young shoot to ascend. The fleshy cotyledons remain within the shell attached for a considerable time to the young plant and providing it with nutriment in its earlier stages.

THE SEEDLING (Fig. 363).

Roots: primary root long, moderately thick, terete, tapering, woody; lateral roots numerous, moderately long, fibrous, distributed down main root. **Hypocotyl** more or less distinct from the root, about 0.1 in. long, thick, subterranean. **Cotyledons** subterranean. **Petiole** 0.2–0.3 in. long, inner surface flattened. **Lamina** 0.7–0.8 in. by 0.35–0.4 in., thick, fleshy, elliptical oblong, apex rounded, base sagittate, forming a prolongation behind the petiole, outer surface rounded, inner flattened in contact. **Stem** erect, terete, green, glabrous; first internode (above cotyledons) 2.5–3.5 in., subsequent internodes 0.2–1.8 in. long. **Leaves** simple, first pair usually opposite, subsequent leaves alternate. **Stipules** 0.2 in. long, linear acuminate. **Petiole** 0.2–0.3 in. long, flattened above. **Lamina**, first pair 0.9–2.3 in. by 0.5–1.5 in., elliptical, ovate or obovate, acuminate, subsequent leaves 1.5–4.5 in. by 0.5–1.3 in., elliptical lanceolate, acuminate, base tapering, sharply serrate, green, glabrous and shining above, glaucous beneath; lateral veins prominent, parallel, 8–12 pairs.

Natural seedlings attain a height of about 5–7 in. during the first season, and nursery-raised seedlings ordinarily attain a height of 6–10 in. by the end of the first and 1–2 ft. or more by the end of the second season. Seedlings eight years old, the result of direct sowings in the Korwa forest, Jaunsar, had a mean height of 3 ft., but this growth is probably below the average, as the locality in which the sowings were made was a somewhat dry one. Experiments at Dehra Dun have shown that seedlings stand a fair amount of shade, but that they die off under heavy shade. The seedlings are rather sensitive to drought, and require a moist soil for their best development.

SILVICULTURAL CHARACTERS. This oak stands a considerable amount of shade, thrives best on moist rich soil, and does not grow well in dry situations. It coppices freely.

NATURAL REPRODUCTION. Under natural conditions germination commences early in the rainy season, about July, but in moist places germinating



FIG. 364. *Quercus glauca*. SEEDLING $\times \frac{3}{8}$

Acorn b—Nut of acorn c - e—Germination stages f - i—Development of seedling to end of first season

seed has been observed early in May. Experiments carried out at Dehra Dun have shown that seed lying in the open exposed to the sun for any length of time invariably cracks and becomes infertile. For successful germination it is essential that the seed should either become buried soon after falling, or lie on very moist ground or under shade. Natural reproduction establishes itself under moderate shade, but after the young plants are well established they benefit by complete light overhead. In very moist almost swampy ground thickets of natural reproduction are sometimes met with.

ARTIFICIAL REPRODUCTION. This oak can be raised successfully either by direct sowing or by transplanting from the nursery. The best time for sowing, both direct and in the nursery, is the early spring, and transplanting from the nursery can best be carried out in the rainy season the year after sowing. Plantations should be made as far as possible in moist ravines and similar places, and not on dry ground.

9. *Quercus lamellosa*, Smith. Buk oak. Vern. *Búk*, Lepcha; *Bujrat*, *shalshi*, Nep. (Fig. 366.)

A large evergreen tree forming in the open a massive spreading crown and a short, often crooked bole, but producing in a close crop a tall clean straight bole. Leaves up to 18 in. long, elliptical-lanceolate, acute at both ends, sharply serrate, glabrous above, glaucous beneath. Bark grey and granular, often with a pinkish tinge in old trees. The stem and branches are almost invariably covered with a thick layer of moss. Wood very hard, durable under cover, used for building; an excellent fuel. This is the most important oak of the Darjeeling hills.

The tree attains a very large size, reaching under favourable conditions a height of 100–120 ft. and a girth of 15–20 ft., while girths up to 40 ft. have been recorded. The largest tree measured recently in the Kurseong forests was 24 ft. 2 in. in girth (H. S. Gibson). Large trees are, however, almost invariably hollow, and it is doubtful if trees much over 7 ft. in girth can be relied on to be thoroughly sound, though sound trees up to 10 ft. in girth or even more are occasionally met with.

DISTRIBUTION AND HABITAT. Eastern Himalaya from Nepal eastwards at 6,000–9,000 ft., Manipur at 7,000–9,000 ft. In the Darjeeling hills the tree is commonest between 6,000 and 8,000 ft. in mixed forest along with maples, laurels, *Michelia excelsa*, *Quercus lineata*, and other trees. It grows on any aspect, as well as on ridges, but thrives best on northerly slopes with deep, well-drained, fairly moist soil. On somewhat clayey loam it tends to become more or less gregarious, while in some old grazed areas the crop in places consists almost entirely of old misshapen buk trees. The climate of the Darjeeling hills is decidedly humid, with a rainfall of over 100 in.

FLOWERING AND FRUITING. The flowers appear in April–May, and the acorns ripen in November–December in the second year, falling soon after. The acorns are very large, broader than long, the cup up to 3 in. in diameter, woody, with a number of lamellae, enclosing the greater part of the nut. The nuts (Fig. 364, *a*) are 0.7–1.1 in. long by 0.9–1.5 in. in diameter, light brown, smooth, shining, with a broad base and a thick prominent, laminated, finely tomentose apiculum; about 45–50 weigh 1 lb. They are very subject to insect attacks, and a great deal of seed is destroyed in this way. The acorns

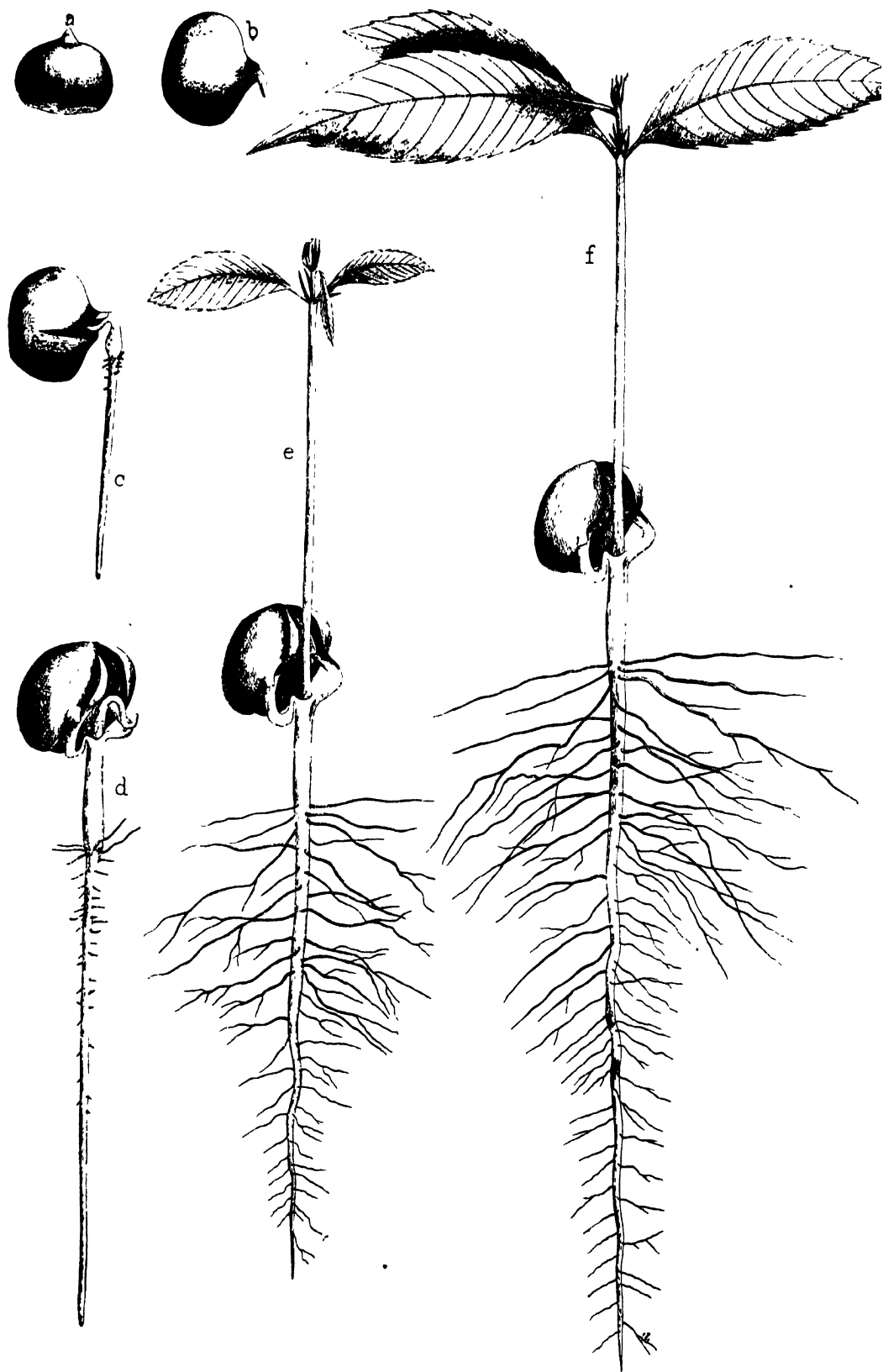


FIG. 364. *Quercus lamellosa*. Seedling $\times \frac{1}{2}$.
 a, Nut of acorn ; b-e, germination stages ; f, seedling six weeks old.

are also greedily eaten by almost all wild animals, including bears, pigs, deer, monkeys, squirrels, and rats, and a considerable portion of the seed-crop is destroyed by them. Records of seed-years show that in the Darjeeling forests out of eight consecutive years the seeding was good in three years, fair in two years, and bad in three years. Ordinarily a good seed-year is expected about once in three years.

GERMINATION (Fig. 364, *b-e*). Hypogeous. The radicle emerges from the apex of the seed, the thick shell of which splits, and the taproot attains some length before the plumule emerges. The emergence of the young shoot is effected by the elongation of the cotyledonary petioles. The young shoot appears from between these petioles and arches during elongation, afterwards straightening. The taproot may attain a length of several inches before the young shoot appears above ground.

THE SEEDLING (Fig. 364).

Roots : primary root long, thick, terete, tapering, somewhat fleshy in young stages, soon turning woody, glabrous ; lateral roots numerous, moderately long, fibrous, distributed down main root. *Hypocotyl* distinct from root, 0.8-1.2 in. long, thick, fleshy, somewhat compressed, tapering slightly upwards, glabrous. *Cotyledons* : petiole 0.9-1.2 in. long, flattened, somewhat fleshy, curved ; lamina thick, fleshy, 0.7-1 in. long by 1-1.2 in. broad, outer surface rounded, rugose, inner flat, base prolonged to a blunt point. *Stem* erect, tapering slightly upwards from base to first node, somewhat compressed below that node, elsewhere terete, young parts woolly tomentose ; internodes, first, from base to first node, 4-6 in., next few 0.4-1 in., in second year up to 2 in. long. *Leaves* simple, first pair opposite, subsequent leaves alternate. *Stipules* 0.3-0.5 in. long, linear acuminate, pubescent. *Petiole* 0.5-0.6 in. long, flattened or channelled above, pubescent. *Lamina* 4-6.5 in. by 1.5-2.5 in., elliptical lanceolate, acuminate, serrate, sub-coriaceous, bright green above, glaucous beneath, minutely pubescent or glabrescent when young, afterwards glabrous, lateral veins 9-12 pairs, often slightly depressed above, prominent beneath.

The growth of the seedling is moderate, an average height-growth of about 1 ft. per annum being usual during the first few years. A long stout taproot is formed from the commencement. Seedlings stand a fair amount of shade, but after their earlier stages they develop best with full overhead light ; they have a tendency to produce numerous side branches, and require to be grown in a close crop for the production of clean stems. Seedlings are frost-hardy, but are sensitive to fire ; they are damaged by grazing, but suffer to a less extent than most species in their habitat.

SILVICULTURAL CHARACTERS. Although shade-bearing in its younger stages, from the sapling stage onwards the tree develops best with full overhead light, but it requires much side shade to prevent the formation of side branches and promote a straight clean bole. It is hardy to frost and drought, but is very susceptible to damage by fire, large trees being sometimes killed outright. It coppices very well, even large trees throwing up healthy shoots. It does not produce root-suckers.

NATURAL REPRODUCTION. Owing to the quantity of acorns destroyed by insects and animals natural reproduction is not so good as it might be, although it is sometimes fairly good in areas which have been closed to grazing for some time. Clean bare ground does not appear to be necessary for germination as

in the case of light seeds, the acorns germinating well on a carpet of undecayed leaves. A canopy sufficiently shady to prevent a dense undergrowth is beneficial, though after the seedlings have established themselves they require more overhead light ; where the undergrowth is dense seedlings are scanty or absent. Mr. Manson¹ states that reproduction is most satisfactory where the soil is rich and light and where there is no grazing, and especially on ridges or where the forest is open or the cover particularly lofty ; he adds that the *maline* bamboo (*Arundinaria racemosa*), which generally grows best on ridges where there is abundant light, and of which the haulms retain the fallen leaves, seems to assist the reproduction of the oak in places where the bamboo itself is protected from cattle. He mentions also that the young plants seem to require protection, and may be found under the shelter of a boulder, stump, or fallen tree, having possibly sprung from acorns which have been left by squirrels or have escaped their notice. Hoeing the soil or clearing the undergrowth round seed-bearers is said to be ineffective, as this only attracts animals and enables them to find the acorns.

ARTIFICIAL REPRODUCTION. Direct sowings have been found to give much better results than transplanting unpruned nursery-raised seedlings, as the long taproot renders transplanting somewhat difficult. Mr. J. R. P. Gent, however, informs me that he has transplanted in the rains with complete success nursery seedlings four years old with stems about 1 in. in diameter, after pruning off the taproot and cutting off the stem immediately above the lowest side branch ; this system would probably be found useful for filling up blanks in young plantations. Whatever method is employed, the seed should be sown as soon after ripening as possible, and certainly not later than January, owing to its liability to insect attacks if kept any time. The seeds require to be sorted carefully, those which are badly worm-eaten being discarded ; seeds which float in water are usually considered unsuitable. In the Kurseong forest division the method usually followed in the case of direct sowings is to loosen the soil to a depth of about 18 in. in patches 1 ft. square and to bury the seeds 3 or 4 in. below the surface ; as a rule two or three seeds are sown in each patch, as germination is somewhat uncertain and the seeds, even in the ground, are liable to destruction by animals. The seedlings ordinarily appear in May, and require to be kept free from weeds and climbers for three or four years. In some places the loosening of the soil prior to sowing is considered unsuitable, as it attracts animals.

For transplanting purposes the seeds are sown in seed-beds in December or January at intervals of about 3 in. and at a depth of about 3 in. ; they are usually pricked out about 1 ft. apart in the nursery when one year old and transplanted when about three years old and 2–3 ft. in height. Transplanting is best carried out in February or March, before the season's growth commences ; it may also be carried out towards the end of the rainy season, about August, after the new leaves have hardened.

RATE OF GROWTH. The annual rings are usually indistinct, but Gamble estimates the growth at about 8 to 12 rings per inch of radius, giving a mean annual girth increment of about 0.5 to 0.8 in.

¹ Darjeeling Working Plan, 1893.

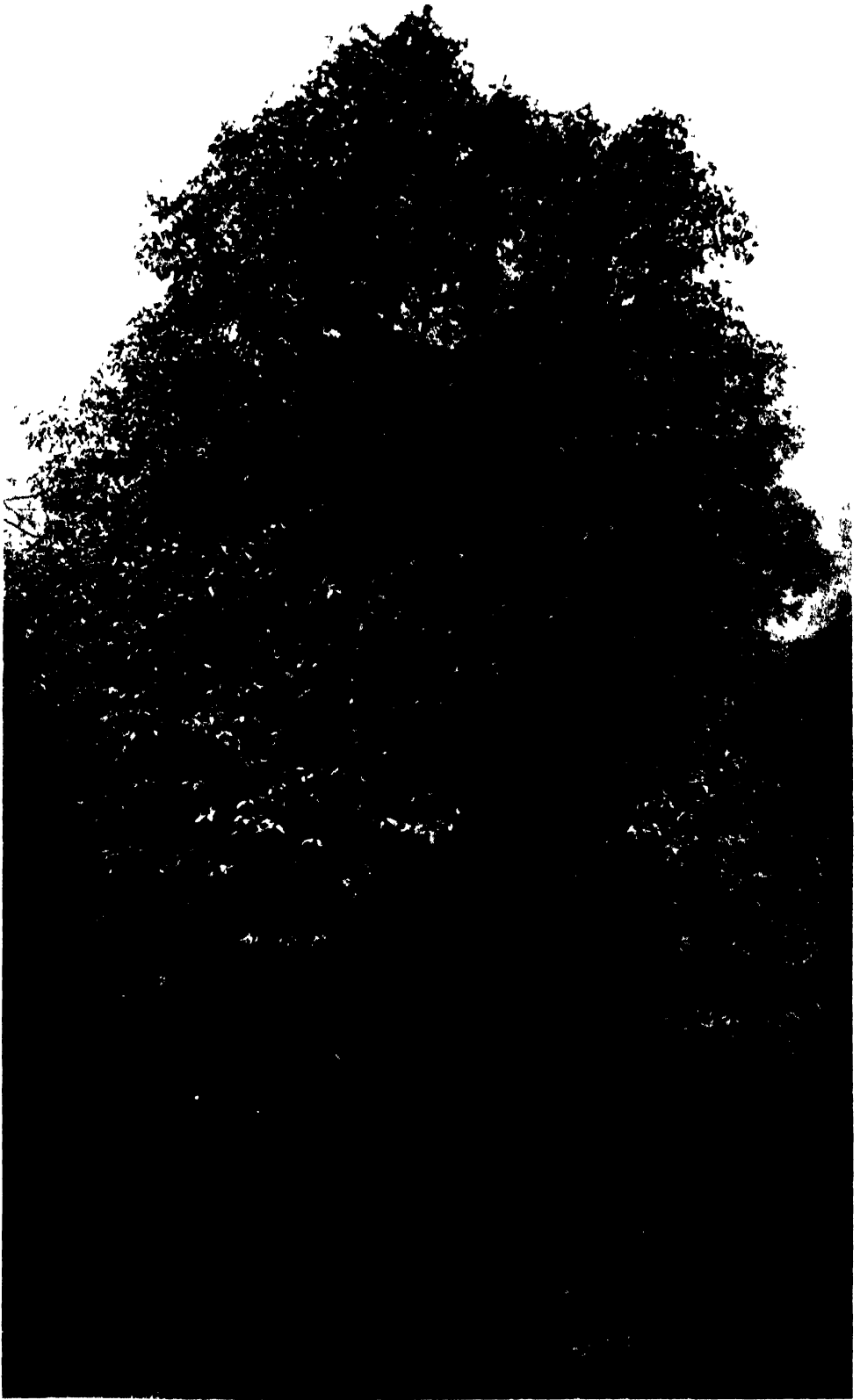


FIG. 365. *Quercus glauca*, girth 3 ft. 4 in., height 40 ft., Kumaun hills.

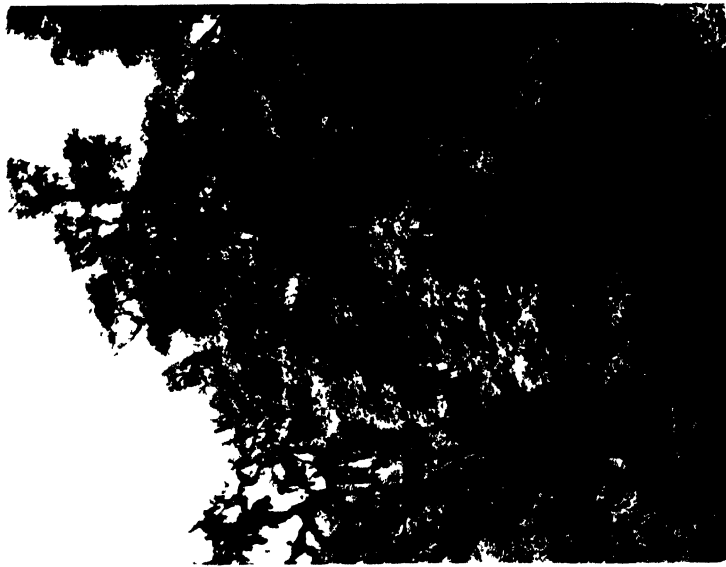


FIG. 366. *Quercus lanellosa*, girth 10 ft., height about 100 ft., bole about 50 ft., Daijeeling hills.



FIG. 367. *Populus ciliata* on island in Kunhar river, Kagan valley, Hazara.

Mr. H. S. Gibson says a girth of 6 ft. is reached in about 120 years, and gives the average growth up to twenty years as follows :

Quercus lamellosa : rate of growth of young trees, Darjeeling hills.

Age. years.	Mean height.		Mean girth.	
	Natural. ft.	Artificial (planted). ft.	Natural. in.	Artificial (planted). in.
1	1	1		
2	2	2		
3	3	3		
4	4	3.5		
5	7	4		
6	10	5		
10	18	8		
15	30	14		
20	40	22	18	10

Mr. J. L. Baker says that measurements recently made in abandoned nursery-beds in the Darjeeling hills indicate that under such favourable conditions trees grown in dense crops might, at the rate of growth exhibited, be expected to attain a girth of 6 ft. in about sixty-two years, at all events at the lower elevations.

10. *Quercus lineata*, Blume. Vern. *Phalat*, Nep.

A large evergreen tree with thick brown rough bark. Eastern Himalaya at 6,000–9,000 ft., Khasi and Naga hills, Arakan, hills of Upper Burma. This is an important tree of the Darjeeling hills ; it is a common companion of the buk (*Q. lamellosa*), and the wood of the two is used almost indiscriminately, though that of the buk is considered somewhat the better. The nut of the acorn is depressed, often broader than long, in a broad shallow cup. The acorns are much subject to the attacks of insects and animals, and natural reproduction suffers in consequence. The treatment of this tree is similar to that of *Q. lamellosa*, and the two are often grown together artificially. Flowers April–May ; fruits September–October (Manson, Darjeeling).

11. *Quercus spicata*, Sm. Syn. *Q. squamata*, Roxb. Vern. *Arkaula*, Nep.; *Bara chakma*, Beng.; *Thitcha*, *sagat*, Burm.

A moderate-sized to large tree with large but very variable leaves, and acorns several close together on spikes. Eastern Himalaya from Nepal eastwards, ascending to 5,000 ft., common in moist *jhoras* or depressions in the Duars ; Assam, Manipur, and dry hills of Burma. Gamble says it is often gregarious, and forms in the Darjeeling hills a sort of coppice wood, preferring somewhat dry exposed ridges, and usually associated with *Engelhardtia spicata* and *Schima Wallichii*. It coppices profusely. Flowers March–April ; fruits September–October of second year (Manson, Darjeeling).

12. *Quercus pachyphylla*, Kurz. Vern. *Bara katús*, *singori katús*, Nep.

A large evergreen tree attaining a height of 80–100 ft. or more and a girth of 15 ft. Var. *fruticosa*, Manipur, is a shrub or small tree. Leaves 5–8 in. long, smooth and greyish. Acorns crowded together into compact masses with cups confluent. Wood of good quality, used for planking, shingles, &c. Sikkim, in the inner hills at 6,000–10,000 ft., usually at higher elevations than *Q. lamellosa*, and common on the Singalila ridge. Manipur at 7,000–9,000 ft. The acorns, which ripen about November, are much subject to the attacks of

insects and animals, and reproduction suffers in consequence. Manson¹ says seedlings are fairly numerous in the neighbourhood of the parent trees. He gives the rate of growth as 8 to 10 rings per inch of radius, representing a mean annual girth increment of 0.63 to 0.78 in.

2. CASTANOPSIS, Spach.

Evergreen trees with erect male catkins and nuts of the fruit wholly enclosed in the involucre, which is covered with spines or tubercles. Twelve Indian species, of which eleven are found in Burma.

Species 1. *C. indica*, A. DC.; 2. *C. Hystrix*, A. DC.; 3. *C. tribuloides*, A. DC.

1. *Castanopsis indica*, A. DC. Syn. *Castanea indica*, Roxb. Vern. *Banj katús*, Nep.; *Thitè*, Burm.

A moderate-sized to large evergreen tree with elliptical oblong sharply serrate leaves and silvery grey bark. Wood fissile and largely used for shingles, as well as for building. Eastern Himalaya from Nepal eastwards, ascending to 6,000 ft.; in Bhutan all along the outer hills up to 4,000 ft. (Jacob); Assam, Chittagong, hills of Upper Burma east of the Irrawaddy. Common in the Darjeeling hills, especially on dry slopes and on abandoned cultivation. Flowers November–December; fruits September–October (Darjeeling). The nut, which is edible, is enclosed in a very prickly involucre. The tree coppices and pollards well. Gamble gives the rate of growth at about 4 to 6 rings per inch of radius, representing a mean annual girth increment of about 1 to 1.6 in., which is fast.

2. *Castanopsis Hystrix*, A. DC. Syn. *C. rufescens*, Hook. f. and Th. Vern. *Katús*, *bara katús*, Nep.; *Hingori*, Ass.

A large evergreen tree, reaching a height of 100–120 ft. and a girth of 15 ft. or more. Leaves lanceolate, with a fine rusty tomentum beneath. Wood much used for shingles and planking in the Darjeeling hills. Sikkim and Bhutan at 6,000–8,000 ft. (common in the Takdah forest, Darjeeling hills); Assam, hills of Upper Burma east of the Irrawaddy and of Martaban. Flowers May; fruits September–October (Darjeeling). The nut, which is edible, is enclosed in an involucre with stellately branched spines. Natural reproduction is fairly good in the Darjeeling hills, and the seedlings stand a good deal of shade for some years. Artificial reproduction is best secured by dibblings *in situ*, the ground being disturbed as little as possible to prevent attracting squirrels, rats, and other animals, which devour the nuts. Transplanting from nurseries has been found difficult. The tree coppices well. Gamble gives the growth at about 8 rings per inch of radius, representing a mean annual girth increment of 0.78 in.

3. *Castanopsis tribuloides*, A. DC. Syn. *Castanea tribuloides*, Wall.; *Quercus ferox*, Roxb. Vern. *Tumari*, *katonj*, Kumaun; *Musre katús*, Nep.; *Thitegyin*, *kyansa*, Burm.

A moderate-sized evergreen tree with lanceolate acuminate leaves, green above and pale beneath. A variable tree with a wide distribution. Outer Himalaya from the Ganges eastwards, ascending to 6,000 ft., evergreen forests of the Duars, Assam, Manipúr, Chittagong, hills of Burma. Flowers March; fruits May (Duars). Nut edible, enclosed in an involucre armed with stout, often clustered spines. The tree coppices very well.

¹ Darjeeling Working Plan, 1893.

3. CASTANEA, Tourn.

Castanea sativa, Miller. Syn. *C. vulgaris*, Lam.; *C. vesca*, Gaertn. Spanish or sweet chestnut.

A native of southern Europe. Cultivated in the Himalaya for the sake of its fruit. It succeeds fairly well up to about 6,000 ft., and grows well at Dehra Dun (2,000 ft.); it tends to branch low, however, and does not produce the height-growth attained in Europe. The fruit ripens well, but it is not of such large size or such good quality as in Europe. In some parts of the Himalaya the trees tend to reproduce naturally. It has succeeded best at fairly low elevations, about 3,000–5,000 ft., on northern aspects, moderately dry regions, and fertile but somewhat sandy soil. In Europe it does not do well in soils containing much lime or in clayey soils, requiring a sandy but deep and fertile soil for its best development. The tree is grown from seed. In Europe it is usual to keep the nuts in dry sand over the winter, as a protection against mice, and to sow them in the nursery in the spring, pricking them out with somewhat close spacing when one year old, and planting them out when two years old. In India the nuts do not keep well, and it is sometimes found advisable to sow them when they ripen, about August or September. The tree is a moderate light-demander; it coppices well, and in Europe is frequently grown as coppice for the supply of poles of different sizes. In Europe it is sensitive to late and early frosts, but in those localities in which it has been cultivated in India it withstands all ordinary frosts.

ORDER LX. SALICACEAE

This order, which comprises the willows (*Salix*) and the poplars (*Populus*), is of somewhat secondary importance in India; with few exceptions its members are confined to the Himalaya. The trees are deciduous, and the flowers are dioecious, in catkins similar in both sexes.

Genera 1. *SALIX*, Linn.; 2. *POPULUS*, Linn.

1. *SALIX*, Linn.

There are 27 known indigenous willows, of which 24 are purely Himalayan, some of them little known, two non-Himalayan, and one (*S. tetrasperma*, Roxb.) extending throughout the greater part of India and Burma, including the outer Himalaya. In addition there are four introduced species, namely *S. alba*, *S. fragilis*, *S. babylonica*, and *S. Caprea*. Another species which has recently been tried on a small scale in Kashmir is *S. coerulea*, the chief willow used in England for cricket bats.

The willows are shrubs or trees, often fast-growing, with soft white or light red even-grained wood. They pollard and coppice vigorously, grow readily from cuttings, and are very useful for planting along river-banks or on unstable hill-sides to fix the soil. The twigs of most willows are used for basket-work, and there is scope for the cultivation of suitable species for the manufacture of baskets for the Himalayan fruit trade.

In raising willows from cuttings straight shoots 2–3 ft. long and 2–4 years old, with well-matured wood, should be selected from pollarded or

coppiced trees ; the cuttings should have a slanting cut at each end. In moist ground thick shoots up to 10 ft. or more in length strike readily, though under ordinary conditions shoots 3 or 4 ft. long and about $\frac{1}{2}$ to 1 in. in diameter are suitable. The cuttings are planted *in situ* in the rainy season, or, if watering or irrigation is possible, in January or early February, before sprouting commences. Where the ground is too dry for the direct planting of the cuttings it may be necessary to plant them in the nursery, watering them and keeping them there until they are well rooted, when they are planted out. Cuttings so treated may be planted in the nursery early in February, before sprouting commences, or in the rainy season.

The Himalayan willows are leafless in the winter, and sprout early in the spring, the flowers appearing with or before the new leaves. The flowers are dioecious, in catkins bearing numerous flowers on a slender axis. The fruit, a small capsule dehiscing into two recurved valves, ripens as a rule 2–3 months after flowering. The seeds are minute, with long silky hairs enabling them to be carried a long distance by the wind. In the Himalaya seedling reproduction springs up readily on newly exposed ground on landslips, in cuttings, on depressions scoured by snow, and similar places ; here willow seedlings may often be found in quantity, and they perform a useful function in fixing unstable hill-sides and preparing the way for the establishment of other trees.

Species 1. *S. tetrasperma*, Roxb. ; 2. *S. Wallichiana*, And. ; 3. *S. elegans*, Wall. ; 4. *S. daphnoides*, Vill. ; 5. *S. alba*, Linn. ; 6. *S. coerulea*, Sm. ; 7. *S. fragilis*, Linn. ; 8. *S. babylonica*, Linn. ; 9. *S. Caprea*, Linn.

1. *Salix tetrasperma*, Roxb. Indian willow. Vern. *Bed, bains, bilsa, laila*, Hind. ; *Bocha, bitasa*, Mar. ; *Niranji*, Kan. ; *Momaka, yenè*, Burm.

A small or moderate-sized, sometimes large deciduous tree, often evergreen in Burma, very variable, with silky pubescent shoots and lanceolate or ovate-lanceolate acuminate leaves. Bark rough, with deep vertical fissures. Wood red, soft, even-grained, used for planking and well-construction, and has been successfully tried for match-manufacture. The twigs are used for basket-work, and the branches are lopped for fodder. It is a useful tree for planting along rivers and streams to support their banks, and for growing on wet ground.

This is the common willow of India, and is found, often growing gregariously along the banks of rivers and streams and in wet swampy places generally, throughout the greater part of India and Burma, ascending to 6,000 ft. in the Himalaya and 7,000 ft. in the Nilgiri hills. The season of flowering and fruiting seems to vary. In northern India the tree is leafless in the cold season, the leaves falling after the end of the rainy season ; the new leaves and the catkins appear in February–March, and the fruit ripens about April, but in some localities flowering takes place in the autumn. Haines¹ says the tree in Chota Nagpur is deciduous in September, the flowers appearing on the new shoots in October and the fruits ripening in December–January ; he adds that in some districts of Bengal it flowers in the hot season. Talbot says in Bombay it flowers in October–November.

The tree grows well from cuttings planted in moist places, and stands flooding, often sending out small rootlets near the base of the stem when

¹ For. Flora Chota Nagpur, p. 402.

subject to inundation. It coppices and pollards well. It is decidedly frost-hardy, and in the great frost of 1905 in northern India it was almost the only tree which escaped injury. In the abnormal drought of 1907 and 1908 in the forests of Oudh it suffered to some extent when the streams and swamps dried up.

The rate of growth is fast. Gamble's specimens gave 2 to 7 rings per inch of radius, representing a mean annual girth increment of 0.9 to 3.14 in. In the Delhi Bela plantation Mr. Minniken found the growth to be 2 to 2½ rings per inch of radius, giving a mean annual girth increment of 2.52 to 3.14 in.

2. *Salix Wallichiana*, And. Vern. *Bhains*, *bhainshra*, W. Him.

A large deciduous shrub or small tree, with young parts silky and leaves lanceolate acuminate, usually entire, when young silvery pubescent on both surfaces or on the under surface. Bark greenish grey. A common species in the Himalaya, extending eastward to Bhutan, chiefly at 7,000–8,000 ft. but ascending to 9,000 ft. and descending almost to the plains. Kurram valley at 10,000–12,000 ft. Flowers March–May, with or before the new leaves. The branches are used for basket-making.

3. *Salix elegans*, Wall. Vern. *Bed*, *báshal*, *bail*, W. Him.

A deciduous shrub. Leaves 1–3 in. long, ovate or oblong, obtuse, rarely acute. Bark greenish grey. The commonest species of the western Himalaya, at 6,000–11,000 ft., growing gregariously and often forming dense, almost impenetrable thickets of some extent. It is a very useful shrub for reclothing new ground and for preventing erosion. It is also a useful nurse for more valuable species, which establish themselves under its cover. The twigs are cut for cattle and goat fodder.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The leaves fall about November–December. The new leaves and flowers appear in March–April, and the fruits ripen in May–June. The seeds (Fig. 368, *a*) are 0.06 in. long, green, pointed at one end, blunt at the other, with numerous long white silky hairs attached to the blunt end.

GERMINATION (Fig. 368, *b–e*). Epigeous. The minute seed swells up, becoming bright green. The thin delicate papery testa at first encloses the unopened cotyledons like a pointed cap, but soon falls and the cotyledons expand. The apex of the radicle is enveloped for a time in the silky hairs of the seed until the young root pushes its way down through them.

THE SEEDLING (Fig. 368).

Roots : primary root long, terete, wiry, flexuose, giving place in second year to a large bushy mass of long fibrous roots ; lateral roots in first year moderate in number and length, distributed down main root. *Hypocotyl* distinct from root, about 0.1 in. long, tapering upwards, glabrous, often slightly curved. *Cotyledons* shortly petiolate, 0.1–0.15 in. by 0.05 in., foliaceous, slightly fleshy, ovate oblong, entire, green, glabrous, apex rounded. *Stem* erect, terete, green and minutely pubescent in first season, previous year's stem greyish green in second season ; internodes up to 0.2 in. in first year, up to 1 in. in second year ; winter buds reddish. *Leaves* simple, alternate. Stipules minute. Petiole up to 0.15 in. long in first two years, flattened or channelled above. Lamina in first year 0.15–1.2 in. by 0.05–0.4 in., in second year 1–2.5 in. by 0.3–0.8 in., ovate- or oblong-lanceolate, acute or acuminate, serrate, bright green above, paler beneath, young leaves pubescent, older leaves glabrous.

During the first season the growth of the seedling is slow ; by the end of the season a height of 0·5 to 2 in. is attained, the number of leaves varying from 5 to 15. During the second season the growth is much faster, the average height at the end of the season being 1½ ft. The seedling requires an abundance of light, soon becoming suppressed under shade ; it is very sensitive to drought, and requires a good deal of moisture in the soil. The seedlings are leafless during the winter, the new leaves appearing as a rule in March. Before falling the leaves are often shrivelled up by frost, which does not affect the stem.

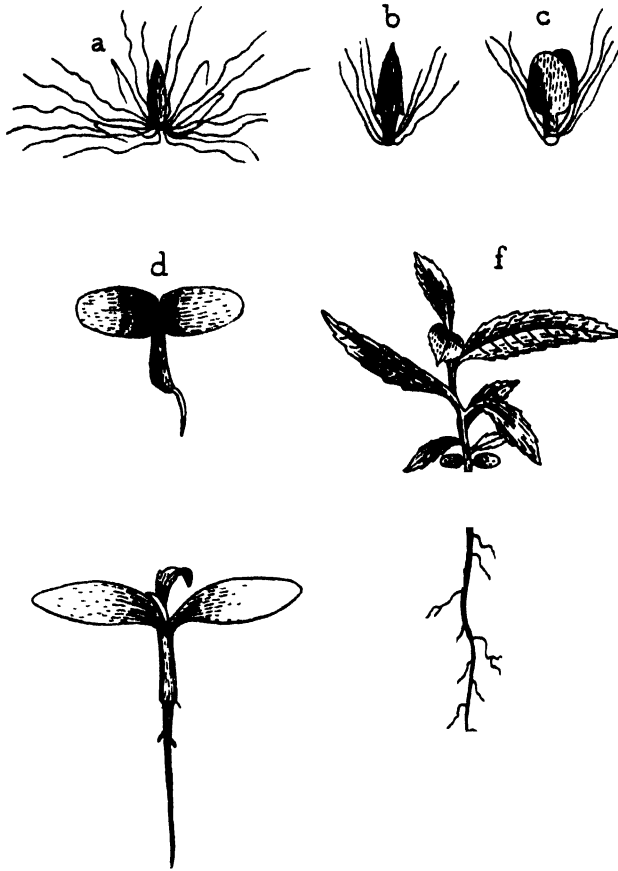


FIG. 368. *Salix elegans*. Seedling.

a, seed $\times 5$; *b-e*, germination stages $\times 5$; *f*, seedling 2½ months old ½.

NATURAL REPRODUCTION. Under natural conditions germination takes place early in the rainy season. This willow, like many others, springs up in abundance on ground newly exposed by landslips, or on depressions scoured by snow sliding down the hill-sides.

ARTIFICIAL REPRODUCTION. This species can be grown readily from cuttings in the manner described in the introduction to this genus. It is also easily raised from seed. Fresh seed should be sown in light soil in boxes during June, the boxes being sheltered from heavy rain and regularly watered. Germination commences in a few days. Where they are congested the seedlings should be pricked out towards the end of the rainy season. They will usually

be large enough to plant out in the following rainy season, though if large plants are required they may be pricked out in the nursery when a year old and finally planted out the following February, before they sprout, or in the ensuing rainy season.

4. *Salix daphnoides*, Vill. Vern. *Bed, bail, bhashli, bashroi*, W. Him.

A large deciduous shrub or small tree. Branches dark green or nearly black, often with a glaucous bloom. Leaves 3–5 in. long, elliptical lanceolate, acuminate, serrate. Bark greenish grey, smooth. Western Himalaya at 2,500–15,000 ft., extending to the inner arid zone. A common species, especially at about 7,000–9,000 ft. Brandis says it attains 60 ft. with a straight erect trunk, 6–7 ft. and at times 9–12 ft. in girth. According to Stewart it is much grown from cuttings in Lahoul between 8,500 and 11,000 ft., generally near water. Flowers March–April, before the new leaves; fruits May–June. The wood is used in the inner arid tracts for building and utensils. The twigs are used for baskets and wattle-work, and the branches are lopped for fodder, the trees in the inner Himalaya being pollarded on a rotation of 3–5 years. It has been employed largely in north Germany for fixing the ground on railway embankments and cuttings and on dry sand-hills, for which its strong long-spreading roots render it particularly suitable (Brandis).

5. *Salix alba*, Linn. White willow.

A large deciduous tree with ascending branches, the branchlets spreading or pendulous. Leaves lanceolate acuminate, upper surface greyish green with silky pubescence, lower surface whitish with dense silky pubescence. Bark light brown, fissured.

Indigenous to Europe, western and northern Asia. Frequently cultivated in the western Himalaya up to 7,000 ft., growing best along water-courses. Flowers March–April.

There is a demand for the wood in the Punjab for making cricket bats. In England, however, the wood of this species is considered of less value for the purpose than that of *S. coerulea*, Sm., and is used only for inferior bats.

6. *Salix coerulea*, Sm. Cricket-bat willow.

This willow is of special importance as being the species whose wood furnishes the best cricket bats. Its introduction into India has recently been attempted, 1,000 cuttings having been imported from England in 1916–17 and planted in the Kitriteng plantation in Kashmir. The experiment did not prove very successful, but in view of the probable demand for the wood it is worth repeating in other localities. The following brief account of this willow is based entirely on the description given by Elwes and Henry.¹

A large tree with ascending branches making a narrow angle with the stem and forming a pyramidal crown. Terminal branchlets erect, not spreading or drooping. Bark smoother than in *S. alba*. Leaves similar to those of *S. alba*, but thinner in texture, more translucent and less densely pubescent, lower surface not white but bluish grey. Most botanists consider this tree a variety of *S. alba*. No male trees are known to exist, and Henry considers it possible that it is a first cross between *S. alba* and *S. fragilis*, with most of the characters of the former dominant. Its growth is much faster than that of *S. alba*, and it produces a wood light in weight, very

¹ The Trees of Great Britain and Ireland, vii. 1763.

elastic and tough and eminently suitable for the manufacture of cricket bats of the best quality.

The tree appears to be confined to the eastern counties of England, where it has been known for over a century. It thrives best on rich light alluvial soil by the side of running streams, and grows well also on moist fertile loam; clay and gravel soils or badly drained marshy ground are unsuitable for it.

The following interesting account by Henry of the cultivation of this willow may be quoted:

'At the present time it is the invariable custom amongst expert growers of cricket-bat willow to use large sets, up to 20 ft. long and 3 in. in diameter, and scarcely smaller than 6 to 10 ft. long by 2 in. in diameter. The sets are best obtained from young trees that have been felled for sale or that have been specially pollarded for the purpose, and should never be taken from the tops of old trees, as these are seldom straight, and require trimming. A young tree, about ten years old, gives the best sets when pollarded, and can be again pollarded every five or six years for six or seven times until decay sets in. The sets should be cut in early spring. Mr. Pratt, after trimming them for four-fifths of their length, has them tied up in bundles of ten and kept in water for a month, after which they are planted out.

'As the willow is a light-demanding tree, and the grower's object is to produce, as quickly as possible, a short stem clean of branches for about 12 to 15 ft., a good crown of foliage must be preserved from the start, and the trees should be planted so wide apart that they do not interfere with each other by lateral shade. If closely planted, they grow more slowly, and often develop an elliptical instead of a circular stem. The distance apart along the side of a stream should not be less than 10 yards. Close planting to kill undergrowth or grass is a mistake, as the latter, if necessary, can be removed by cultivation, though this is seldom done.

'Holes may be made for the sets by driving in a stake two or three feet deep, which can afterwards be levered out. The sharpened end of the set is then dropped into the hole, and tightly rammed in position. It is very important to insert the set deeply and firmly, so that it may not be shaken by the wind. The after care consists in rubbing off in the first three years, with the gloved hand, as high up as possible, the buds which appear on the stem, so as to prevent the development of side shoots. Mr. Pratt advocates the pruning of the stem afterwards to a height of 25 ft., but this is seldom if ever done in Herts. or Essex, where growers are content with a stem clear of branches to 12 or 15 ft.

'Willow trees become saleable to bat-makers when about 15 in. in diameter at six feet from the ground, or about 13 in. at twelve or fifteen feet up. The original set remains as a useless core in the centre of the stem. As the width of a bat is about $5\frac{1}{2}$ in. and the clefts are taken radially, the minimum diameter should be $5\frac{1}{2}$ in. + $5\frac{1}{2}$ in. + 2 or 3 in. (the diameter of the set) = 13 or 14 in. The trees may of course be allowed to grow for another period of years, until a second ring of clefts is formed around the first ring, or even for a further period; but it is usually most profitable to dispose of the trees when they are young.

'The trees are generally sold standing, and are deemed of first quality when the stem is straight, clear of knots or branches, and covered with a smooth scaly bark, which is indicative of rapid growth. As the length of a bat is about 28 in., the trees as soon as felled, which is done in winter, are cross-cut into lengths of 28 to 30 in., and these in turn are split into clefts. The clefts are split up along the radii, so that the annual rings run from the front to the back of the bat. The best clefts come from the lower part of the tree, which is far tougher than the upper portion. In the best bats I have counted from seven to nine annual growths.'



FIG. 369. *Populus ciliata* in ravine running through forest of *Pinus excelsa*, Hazara.

7. *Salix fragilis*, Linn. Crack willow.

A moderate-sized deciduous tree with lanceolate serrate leaves terminating in a long oblique acuminate apex, and each serration terminating in a reddish brown gland. Branchlets easily breaking off at their insertion, especially in spring. Bark rough, with prominent ridges alternating with deep broad fissures.

Believed to be indigenous throughout the greater part of Europe and in western Asia. Cultivated in the Kurram valley, Gilgit, Ladak, Lahoul, and Baluchistan. It requires more moisture than *S. alba*, growing chiefly along the banks of rivers, streams, and lakes. In Europe the growth is moderately fast, but a specimen from Lahoul showed 11 rings per inch of radius (Gamble), giving a mean annual girth increment of 0.57 in., which is rather slow.

8. *Salix babylonica*, Linn. Weeping willow.

A small or moderate-sized picturesque deciduous tree with spreading branches and long pendulous branchlets. Bark rough, with fissures and ridges.

The original home of this willow is believed to be central and southern China, where it occurs along the banks of rivers and water-courses. It is extensively cultivated in Europe and in other parts of the world. It is frequently seen in cultivation in northern India, from the plains up to 9,000 ft., and in Baluchistan; it thrives best at comparatively low elevations, up to about 5,000 ft. It is grown to a small extent along irrigation channels in the Changa Manga plantation in the Lahore district, where there is a limited demand for the wood for cricket bats, though the price received is small; it is found, however, to be short-lived, and when the trees die they decay rapidly. In India the new leaves and catkins appear in February–March, and the fruit ripens about two months later. The male tree is much commoner than the female.

In Europe the young shoots are very liable to be killed by frost, as the tree sprouts early. It thrives best in comparatively warm climates and in moist soil beside running water. It strikes readily from cuttings and grows rapidly in suitable localities. A cross-section in the silvicultural museum at Dehra Dun showed 27 rings for a girth of 3 ft. 3 in., giving a mean annual girth increment of 1.44 in. According to Gamble the growth is usually about 4 to 5 rings per inch of radius, giving a mean annual girth increment of 1.26 to 1.57 in.

9. *Salix Caprea*, Linn. Sallow, goat willow.

A small tree with oval or elliptical leaves with an undulate or crenulate, rarely entire margin; stipules large and reniform. Bark smooth and greenish in young trees, afterwards fissured.

Indigenous to Europe and northern Asia. Cultivated in the Punjab, chiefly along river banks. It is less exacting than most willows as regards soil, growing on dry and even rocky ground, as well as in swampy localities. It grows readily from cuttings, and is useful for fixing shifting soil and river-banks. It is often little more than a shrub. Flowers February–March, before the leaves.

2. *POPULUS*, Linn.

There are six species of poplar in India, either indigenous or introduced, of which *P. ciliata*, Wall., and *P. euphratica*, Olivier, are the most important; the others either are planted for shade or ornament or are quite local. The

poplars are soft-wooded, usually fast-growing trees. Most of them produce root-suckers in great abundance, pollard well, and grow readily from cuttings. The coppicing power appears to vary. The minute seeds, enveloped in tufts of long white silky hairs, are distributed by the wind, and seedlings spring up on newly exposed or recently formed ground (see under *P. ciliata* and *P. euphratica*). Much of the seed is infertile, and germination appears to be successful only under special conditions (see under *P. ciliata*).

Species 1. *P. ciliata*, Wall.; 2. *P. nigra*, Linn.; 3. *P. alba*, Linn.; 4. *P. euphratica*, Olivier.

1. *Populus ciliata*, Wall. Himalayan poplar. Vern. *Safeda*, *piplás*, *pahari pipal*, *chelaun*, *chalni*, *ban pipal*, *bagnu*, W. Him.

A large deciduous tree with a tall clean straight bole. Leaves broadly ovate acuminate, usually with a cordate base; margins serrulate-crenate and ciliate. Buds viscid and resinous. Bark of young trees and branches smooth greenish grey, that of old trees dark brown, rough, with deep vertical fissures. Wood whitish to greyish brown, sometimes yellowish brown in the centre, soft. It is not much used in the Himalaya owing to the presence of coniferous woods which are more in demand; it has, however, been pronounced excellent for match manufacture. This is a useful tree for afforestation purposes on unstable hill-sides. Under favourable conditions it reaches large dimensions. In 1918 I measured three trees in Hazara with girths of 9 ft. 8 in., 11 ft. 1 in., and 12 ft. 9 in., with estimated lengths of clear bole of 50 ft., 70 ft., and 50 ft. respectively, and estimated heights of 100 to 120 ft.

DISTRIBUTION AND HABITAT. Himalaya from Kashmir to Bhutan, at 4,000–10,000 ft. In the western Himalaya it is a common and conspicuous tree in mixed broad-leaved, oak, and coniferous forests. It is capable of growing on dry hill-sides, where it sends up numerous suckers; in such places it does not attain large dimensions. In coniferous forests it is perhaps most frequently associated with blue pine, and trees of large size are often found in ravines running through blue pine forests (Fig. 369); it is also frequently found with deodar, spruce, or silver fir. In the upper Siran valley there are some very fine specimens, with tall straight boles, growing in forests of spruce and silver fir. As a rule the poplar reaches its largest dimensions in ravines in mixed broad-leaved forests, associated with *Aesculus indica*, *Prunus Padus*, *Cedrela serrata*, *Ulmus Wallichiana*, maples, and oaks. In places it is found, usually in pure patches, on islands in the beds of streams, as along the Kunhar river in the Kagan valley, Hazara (see Fig. 367), and in the Kishanganga valley, Kashmir. It thrives best on a well-drained porous soil.

LEAF-SHEDDING, FLOWERING, AND FRUITING. Some trees commence shedding their leaves early in September and are almost leafless by the end of that month. Others shed them later, but all are leafless as a rule by the end of November. The new leaves appear towards the end of March or early in April, the catkins appearing immediately before the young leaves. The male catkins are 3–6 in. long, yellow, pendulous; the female, on separate trees, are also pendulous, but are somewhat stiffer and greener. The female tree is much commoner than the male. The fruits ripen in June, the catkins elongating to 6–12 in. and the 3- or 4-valved capsules opening and permitting the minute seeds, enveloped in silky down, to escape. During June the air in the neigh-

bourhood of poplar trees is full of flecks of down floating about in the breeze. This is objected to in some hill stations, and the tree is discouraged in consequence, and ruthlessly lopped or cut. A more sensible arrangement would be to plant cuttings of male trees and to encourage the growth of what is a decidedly handsome and interesting tree.

The seeds (Fig. 370, *a*) are about 0.05 in. long, light brown, covered with minute bristles by means of which they cling to the masses of silky down. The fine white silky hairs attached to the seeds are 0.25–0.35 in. long; these hairs are easily separated from the seeds, and are then found to be attached together at their bases in threes. A large proportion of the seeds are infertile; the maximum I have obtained in various tests is 23 per cent. of success. Possibly the scarcity of male trees may account for the want of fertility of much of the seed.

GERMINATION (Fig. 370, *b–f*). Epigeous. The testa splits longitudinally down one edge like a follicle and the radicle emerges. There is slight arching of the hypocotyl, and the cotyledons, enclosed in the testa, are raised above ground by the elongation of the hypocotyl; the testa falls to the ground with the expansion of the cotyledons.

THE SEEDLING (Fig. 370).

Roots: primary root moderately long, terete, tapering, thick after first season; in first season a taproot often not developed; lateral roots numerous, long, fibrous. **Hypocotyl** distinct from root, 0.2–0.4 in. long, terete, white turning pale green to reddish green. **Cotyledons**: petiole 0.06–0.08 in. long; lamina 0.08–0.12 in. by 0.08–0.12 in., foliaceous, broadly ovate, sometimes broader than long, apex rounded, base rounded or truncate or broadly cordate, entire, green, glabrous. **Stem** erect, terete; in first year glabrous, usually reddish, internodes up to 0.3 in. long, terminal bud red; in second year reddish green marked with whitish lenticels, young parts minutely pubescent, older parts woody, glabrous, internodes up to 1 in. long, terminal bud red; in third year new season's shoot reddish green with whitish lenticels, previous year's shoot greenish grey, smooth, marked with pale-coloured lenticels. **Leaves** simple, alternate. Stipules triangular or falcate acuminate, up to 0.15 in. long in first three years. Petiole slightly flattened above or channelled, usually red, minutely pubescent, in first year up to 0.15 in., in second year up to 0.6 in., in third year up to 1.3 in. long. Lamina in first year 0.3–1.2 in. by 0.15–0.5 in., oblong or ovate lanceolate, apex and base acute, first one or two leaves distantly serrulate, subsequent leaves serrate, green, glabrous, or in young leaves pubescent beneath, veins and tips of serrations usually reddish; in second year 0.5–5 in. by 0.3–1.7 in., oblong lanceolate, acuminate, base acute or rounded, serrate, green and glabrescent above, whitish and pubescent beneath, venation reticulate, veins slightly depressed on upper surface, principal veins on upper surface and tips of serratures reddish; in third year up to 5 in. by 2.5 in., ovate, acute or acuminate, base cordate or rounded, serrate, upper surface green and glabrescent or in young leaves minutely pubescent, lower surface whitish and pubescent, venation reticulate, veins slightly depressed on upper surface, principal veins on upper surface and tips of serratures reddish.

During the first season the growth of the seedling is slow; by the end of the season it attains a height of 0.5–1.3 in., with 4–7 small leaves and a bushy fibrous root-system up to 2 in. long. Subsequent growth is faster. Artificially raised plants were found to attain a height of about 1 ft., with 15–20 leaves, by the end of the second season, and 2½ ft. by the end of the third season.

Natural seedlings grow more slowly. Of several examined the mean height during the first five years was : first year, 1.4 in. ; second year, 3.7 in. ; third year, 5.1 in. ; fourth year, 7 in. ; fifth year, 16 in., with a taproot 1 ft. long.

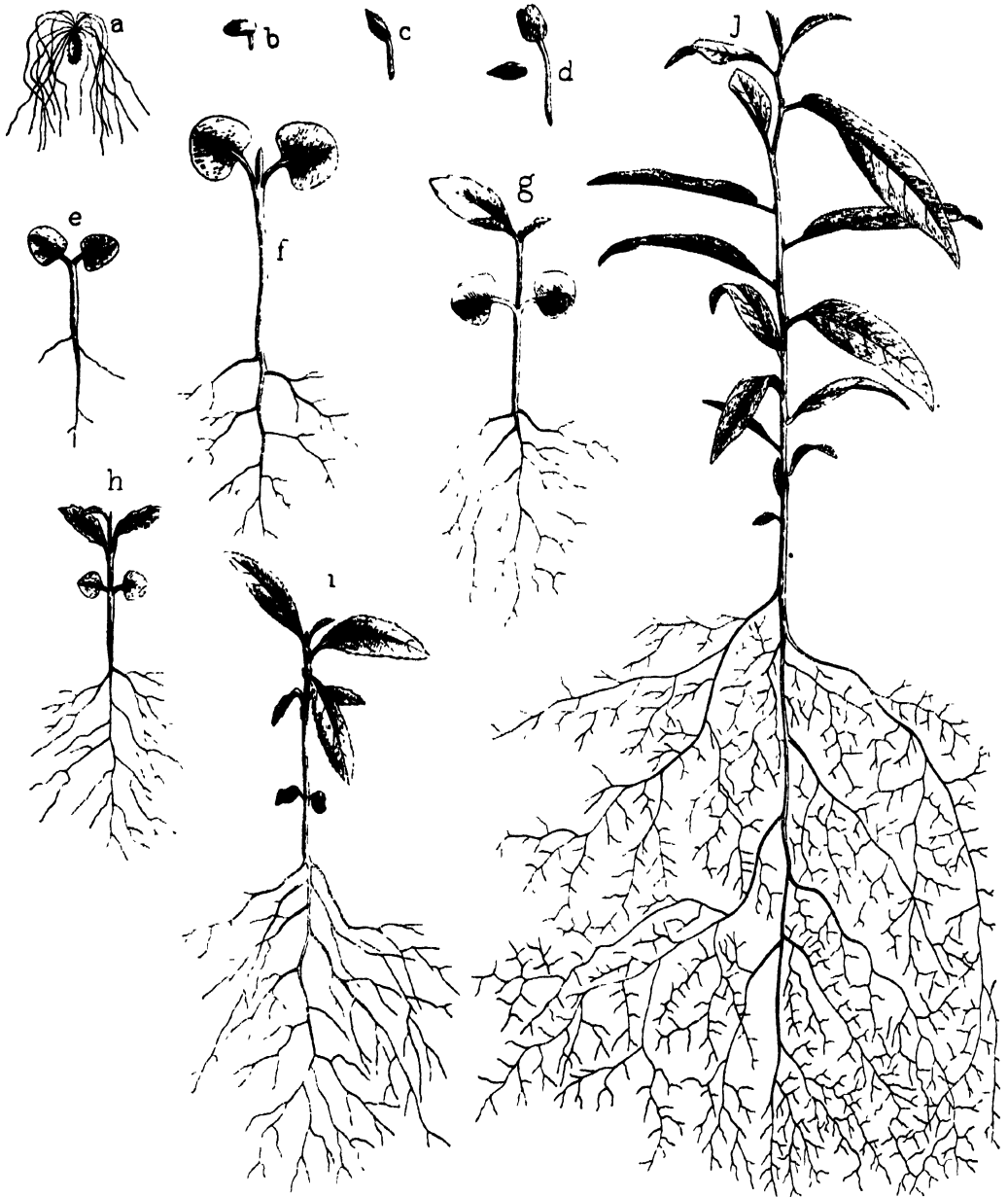


FIG. 370. *Populus ciliata*. Seedling.

a, seed $\times 2\frac{1}{2}$; *b-f*, germination stages $\times 2\frac{1}{2}$; *g-i*, development of seedling during first season, *g* $\times 1\frac{1}{2}$; *h, i* $\frac{1}{2}$; *j*, seedling towards end of second season $\times \frac{1}{2}$.

The leaves of seedlings fall in November–December, that is, later than those of adult trees ; those of young seedlings often turn a deep red colour before falling. New growth starts in March–April. The seedling requires a light porous soil, and tends to damp off in water-logged ground. The leaves

of seedlings are sometimes touched by early frosts before falling and by late frosts after sprouting ; in frosty localities the stems may be killed down during the winter, but new shoots are readily produced from the base.

SILVICULTURAL CHARACTERS. This tree is a light-demander ; it springs up chiefly on open ground, and stands little shade even in youth. It pollards vigorously, but its coppicing power appears to be poor except in the case of young trees. It has an extraordinary capacity for producing root-suckers, and parent trees may often be found sending up quantities of suckers within a considerable radius. On hill-sides where the soil is exposed, or on rocky ground, suckers often appear in great profusion even from roots of large size. Natural layers are sometimes produced, when young branches lying along the ground become covered with earth and send out roots. The tree stands drought well.

NATURAL REPRODUCTION. Under natural conditions the seed, which reaches the ground shortly before the rainy season, germinates a few days after the commencement of the rains. The silky down round the minute seed seems to form a protective covering, preventing the seed from being washed away and retaining moisture during germination. Many of the minute seedlings must be washed away by heavy rain in the earlier stages, but some survive, since natural seedlings are occasionally met with, as a rule in crevices of rocks or on newly exposed ground. Seedling reproduction never springs up on ground covered with grass or weeds or under cover, but only on exposed rocks or in places where the soil has been recently exposed, such as landslips and cuttings, and on alluvial boulder deposits in the beds of streams. By far the commonest form of natural reproduction is by root-suckers.

ARTIFICIAL REPRODUCTION. Owing to the minute size of the seed and the seedling in its earlier stages direct sowings are out of the question, while the usual methods of raising nursery plants are also inapplicable. The only method by which I have been able to raise seedlings with success is to sow the seed in June, soon after collection, on the surface of powdered brick or fine sand in pots or boxes kept under cover but well exposed to the light. Frequent and regular watering is required, and germination takes place in a few days. Care is necessary, during watering, not to wash the minute seedlings out of the ground. The soil should never be allowed to cake, and weeds should be removed wherever they appear. By October the seedlings will average about 1 in. in height, and they should then be pricked out 3 or 4 in. apart in boxes of light sandy soil. These boxes should be protected from frost during the winter by means of a thick covering of thatch or by being placed under the cover of a shed. In the early spring the boxes should be placed in the open, but where late frosts are to be feared it is advisable to protect them at night by a covering of thatch ; water should be given regularly but sparingly during the dry season. About August, after the rainy season has well started, the seedlings, now several inches high, should be pricked out about 18 in. apart in well-raised nursery-beds of light sandy loam and kept there through the winter. Next February, before sprouting commences, they should be finally planted out ; by this time they are about 1 ft. high. Planting can also be carried out successfully during the rainy season, but the risk of failure is greater. If large plants are required, for instance

for roadside planting, the seedlings may be kept for another year in the nursery.

The more usual method of raising poplar is by means of cuttings. These may be either planted *in situ* during the rainy season or kept in the nursery until well rooted before being planted out. I have found the latter the more successful method, very good results having been attained in the following manner. The cuttings should be selected from straight vigorous pollard or coppice shoots or root-suckers. The best results are obtained with wood of the previous year, the cuttings being about $\frac{1}{2}$ to $\frac{3}{4}$ in. in diameter at the thick end ; for upright planting a length of about 12–18 in. is convenient, the cut being a slanting one at either end, while for horizontal planting a length of about 9 in. suffices. The cuttings should be taken in February, before sprouting commences, and planted about 6 in. apart in nursery-beds of light porous soil. They may be either put in the ground upright with a slant in the usual way, or completely buried horizontally about an inch below the surface ; the former method has been found somewhat more successful than the latter. Regular watering and weeding should be carried out throughout the hot season, but no further watering is necessary or advisable after the rainy season commences, by which time the cuttings will have become well rooted. The rooted cuttings can, if desired, be planted out during the rainy season, but this is not advisable, since the chances of failure are much greater than if they are kept in the nursery until the following spring. The best results have been attained by planting out in February before sprouting commences, that is, a year from the time of taking the cuttings.

RATE OF GROWTH. The growth is fairly fast, especially in the case of young trees. A cross-section in the silvicultural museum at Dehra Dun showed 33 rings for a girth of 2 ft. 11 in., giving a mean annual girth increment of 1.06 in. The bark thickness was 0.75 in. Gamble gives the average as about 8 to 9 rings per inch of radius, representing a mean annual girth increment of 0.7 to 0.78 in. Rooted cuttings raised in the nursery and transplanted in the early spring when a year old put on a height-growth of 3 to 5 ft. during the first season.

2. *Populus nigra*, Linn. Black poplar.

A large tree with viscid buds and branchlets and almost triangular acuminate leaves, though these vary greatly. Bark grey or greyish black, rough, deeply furrowed in old trees. The typical form is widely distributed in Europe, but is not cultivated in India. The fastigiate form, the Lombardy or pyramidal poplar (var. *italica*, Du Roi ; var. *pyramidalis*, Spach), is frequently planted in the western Himalaya up to 12,500 ft., particularly in Kashmir ; it is readily recognized from its numerous small branches growing upwards in brush-like form close to and covering the stem, forming a long narrow cylindrical crown. It rarely flowers in India. It is easily raised from cuttings or from root-cuttings, and pollards well. Root-suckers are not often produced while the tree is living, but when it is cut down numerous suckers spring from the roots. The tree will grow on comparatively dry ground, and is useful for fixing unstable slopes. The growth is rapid.

3. *Populus alba*, Linn. White poplar. Vern. *Chitta bagun*, *safeda*, W. Him.

A large deciduous tree with young branches and buds densely white

tomentose. Leaves very variable in size and shape; petioles and under surface densely white tomentose. Bark on young stems smooth, light grey or whitish; on old trees dark, rough, and furrowed, especially near the base. In Afghanistan the wood is used for making grape-boxes.

The white poplar is wild and cultivated in the western Himalaya at 4,000–10,000 ft., extending west to Europe, especially in the Mediterranean region, and north to Siberia; it is also planted in the Punjab plains, Sind, Baluchistan, and elsewhere, but does not do well in the plains. It occurs to a limited extent in the Murree hills with *Populus ciliata*, maple, horse-chestnut, and other trees. It is common in parts of the Kagan valley on hill-sides from 6,000 ft. upwards, where it is wild and possibly indigenous; here it is associated with *Populus ciliata*, *Pinus excelsa*, *Cedrus Deodara*, and other trees, and is similar in habit to *Populus ciliata*, springing up on newly exposed ground and on recently formed alluvial deposits in the beds of streams. It is sometimes found on steep slopes with shallow soil on hot aspects, and as it stands a dry climate it should be useful for afforesting dry slopes. It requires deep moist soil, however, to attain a large size. It produces suckers freely, and can be propagated by transplanting suckers or root-cuttings. It also grows readily from cuttings. In Europe it is considered inferior in pollarding power to *P. nigra*. The growth is fast.

4. *Populus euphratica*, Olivier. Sind poplar. Vern. *Báhan*, *bhán*, Sind, Pb.; *Padar*, Bal.

A moderate-sized or large tree with very variable leaves, those of young plants and coppice and pollard shoots linear, 3–6 in. long, shortly petioled, usually entire, those of older trees on normal branches usually broadly ovate, rhomboid or cordate, long petioled, dentate or variously lobed. Bark thick, with irregular vertical furrows. Wood moderately hard, with red heartwood, used mainly for building and turnery, the lacquered articles in Sind being made as a rule from this wood; it has been pronounced suitable for match manufacture.

In Sind the tree reaches a height of about 40–50 ft., with a girth of 5–8 ft. and occasionally up to 10–12 ft.; at high elevations it is a smaller tree. It produces a clean bole up to 20 or 25 ft. in length, but the bole is seldom perfectly straight.

DISTRIBUTION AND HABITAT. This tree furnishes a remarkable example of a species which extends in elevation almost to the upper limits of tree-growth, and is yet indigenous and thrives in the hottest climate of the Indian plains under the mitigating influence of river inundations.

In India the chief home of the tree is in the forest belt along the Indus in Sind, particularly in the upper and middle parts of the province. It is also found in the southern Punjab along the Sutlej river below Ferozepore, in the valleys of the Suliman range up to 3,000 ft., and in Baluchistan on tributaries of the Indus river. In the upper reaches of that river and its feeders it is found in Ladak and Tibet, especially along the Shayok river at 10,500 ft., ascending to 13,500 ft. Westward it is indigenous on riverain areas in Afghanistan, Turkestan, Persia, Mesopotamia, and Palestine. Parker¹ mentions that it is common in the Jhok forest on the Ravi, and stray specimens

¹ For. Flora Punjab, p. 509.

occur near Baloki, but that as neither Stewart nor Brandis mentions the bahan on the Ravi it is possible that these trees are not wild, but have spread from trees planted in Shahdara plantation.

The tree is typically gregarious, occurring pure or associated with a few other species on the alluvial ground of riverain tracts. The riverain forests along the Indus in Sind have already been described under *Acacia arabica* (Vol. II, p. 421) and under *Tamarix* (Vol. I, p. 16). In these tracts the poplar springs up in abundance on new alluvial deposits along with *Acacia arabica*, *Tamarix dioica*, and *T. Troupii*, and to a lesser extent with *Prosopis spicigera*, which, however, appears more commonly on land which has become elevated above the reach of all ordinary floods. Often the poplar occurs as a standard over an underwood of tamarisk.

In Sind and the southern Punjab the tree experiences a very dry climate which becomes excessively hot in the hot season. The absolute maximum shade temperature varies from about 120° to nearly 125° F., and the absolute minimum from 29° to 35° F., while the normal rainfall varies from 3 to 8 in. It is able to survive in this excessively hot, dry climate only by reason of the annual river inundations. At the higher elevations of its natural habitat the rainfall is also scanty, while extremely low minimum temperatures have to be endured.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The tree is leafless or nearly so from January to March. Before falling the leaves assume a rich golden colour, and a poplar forest in upper Sind at this time presents beautiful colouring. The flowers, in lax catkins, the male 1–2 in. and the female 2–3 in. long, appear in January–February, when the trees are leafless or have only a few old leaves on. The fruits ripen from April to June, the small capsules opening into three, rarely two valves, and the minute seeds, surrounded by silky hairs, being disseminated by the wind.

SILVICULTURAL CHARACTERS. This tree is a decided light-demander. The root-system is mainly superficial, and the tree produces root-suckers in abundance to a considerable distance from the parent tree, the production of suckers being stimulated in areas overrun by fire. Owing to the superficial root-system the trees, particularly large ones, are liable to be blown down when the ground becomes softened by inundations. The tree stands flooding for a time only, and does not survive on low-lying ground liable to prolonged inundation; it survives longer than *Acacia arabica* in the absence of water. It is frost-hardy in its natural habitat. In its earlier stages it suffers much from browsing by cattle and goats. It coppices well up to a large size, and stands pollarding for a long time.

NATURAL REPRODUCTION. Natural seedlings often spring up in quantity on newly formed riverain alluvial ground after the annual floods subside; for its successful establishment it is necessary to exclude grazing and to protect from fire. Much of the reproduction in the poplar forests consists of root-suckers.

ARTIFICIAL REPRODUCTION. Artificial reproduction by seed has been tried in Sind without success. Possibly the method of raising seedlings in pots or boxes, as described for *Populus ciliata*, might prove successful. The tree can be propagated from cuttings, but this method has not been resorted to with any great success for regular planting operations.

SILVICULTURAL TREATMENT. In the riverain forests of Sind the principal species is *Acacia arabica*, and the system of management is adapted mainly to the requirements of that species ; this consists of clear-felling with natural combined with artificial reproduction, the rotation being as a rule thirty years. Under this system the poplar reproduces freely by coppice-shoots and root-suckers, while on newly formed alluvium seedling reproduction springs up. In order to attain the best results it is necessary to exclude grazing from areas bearing young crops. The tree is well adapted for treatment under coppice or coppice-with-standards, reproduction being obtained from root-suckers as well as from coppice-shoots.

RATE OF GROWTH. The growth is rapid. Brandis gives 3 to 4 rings per inch of radius, representing a mean annual girth increment of 1·57 to 2·1 in. Figures received from Sind show that a height of 50 ft. is attained in about thirty years, and a girth of 8 ft. may be reached in fifty years.

ORDER LXI. PALMAE

The palms are among the most interesting and important, as well as the most beautiful, of all the woody members of the vegetable kingdom. The most important, from an economic point of view, are those, such as the coconut, date, palmyra, betel-nut, and other palms, which are cultivated for the production of oils, fibres, and edible and other products ; these as a general rule are not of special importance in Indian forestry. On the other hand, there are certain forest species which have an extensive local use for thatching and other purposes, while several of the rattan canes are regularly exploited ; other forest species, again, like *Caryota urens* and *Corypha umbraculifera*, yield edible and other products, while the palmyra (*Borassus flabellifer*) and the wild date palm (*Phoenix sylvestris*) are forest trees in some localities. Nevertheless, the importance of the cultivated palms, from an economic point of view, far outweighs that of the forest species, most of which are of botanical rather than of economic interest. Hence, since the cultivation of the more important palms belongs to the realm of agriculture rather than of forestry, our treatment of this order must necessarily be brief and confined to a few species which are of economic importance or are particularly common.

The adult palm usually has an erect woody, cylindrical, unbranched stem bearing a crown of leaves at its summit. In many species, however, the stem does not rise above ground, and the visible portion of the plant has the form of a tuft of leaves rising straight from the ground ; *Phoenix acaulis* is the commonest species of this type. In the canes and rattans (*Calamus*) the internodes are long and the slender stems are often scandent, climbing to a considerable height through the tree-growth. In some palms the stem is quite smooth, while in others it is covered with annulations, the scars of former leaves ; in several species the stem is surrounded with a fibrous covering, while in some it is armed with formidable spines. Branching is rare, and is confined mainly to a few species of the genus *Hyphoene*.

The stems of palms consist normally of an outer hard zone of numerous thick-walled fibro-vascular bundles with intervening parenchymatous tissue

and an inner soft portion occupying the centre of the stem and consisting mainly of parenchymatous tissue. The fibro-vascular bundles from the leaves, when they join the stem, first bend inwards towards the centre and then outwards and downwards near the periphery, where they are closely packed together and form the hard outer zone of the stem. Growth in thickness does not, as in the case of dicotyledonous trees, take place by the addition of new external layers of wood produced from the cambium zone, but by general growth within the stem, causing it to increase in thickness until it attains its full size, when further increase in diameter ceases.

The leaves, which form a graceful tufted crown, are often of very large size. They are of two main types, the palmate and the pinnate, whence the popular terms fan-palm and feather-palm respectively. The leaf is entire in the bud, but splits or tears into strips or segments as expansion takes place. The petiole has a broad sheathing base. Leaf-shedding does not take place with regularity as in the dicotyledons. When the leaf has reached the end of its life-cycle it gradually dies, falls over and decays, the basal sheath in some species persisting for a considerable time on the stem. The leaves of seedlings are usually undivided.

The inflorescence is generally lateral, or in a few species terminal; it consists of a much-branched panicle or sometimes a simple or compound spike on a common, often thick peduncle (spadix), and is enclosed in the bud by sheathing bracts (spathes). Where the inflorescence is terminal, as in *Corypha umbraculifera*, the palm flowers once after many years, and then dies after fruiting. Where the inflorescence is lateral the plant may flower year after year, the spadix dying and falling off after fruiting.

The flowers are monoecious, dioecious, or polygamous, rarely bisexual. The male and female flowers often occupy different portions of the same spadix, the female below and the male above, or in some species the male and female may be intermingled on the spadix. The flowers are 3-merous, usually with three sepals, petals and carpels, and six stamens. In the fruit two of the carpels may become abortive, only one seed resulting, as in the coco-nut. The fruit is a drupe or a berry. The seed has a small embryo and a large endosperm, which is sometimes oily, sometimes hard and horny, and occasionally mucilaginous.

The palms are essentially characteristic of the tropical regions of the globe, the number of species being richest where the humidity is greatest; this applies likewise to the Indian region, where the species are most numerous in the moister parts of Burma, the Andamans, the eastern Himalaya, and the west coast, including the Nilgiri and other hills of southern India. Among the commoner palms of the drier but not arid regions of India, indigenous or cultivated, are *Phoenix acaulis*, *P. humilis*, *P. sylvestris*, and *Borassus flabellifer*. Perhaps the best Indian example of an arid region palm is *Nannorhops Ritchieana*, which grows gregariously in the dry tracts of the trans-Indus country.

Genera 1. PHOENIX, Linn. ; 2. ARECA, Linn. ; 3. COCOS, Linn. ; 4. NIPA, Wurm. ; 5. CALAMUS, Linn. ; 6. CARYOTA, Linn. ; 7. NANNORHOPS, H. Wendl. ; 8. LICUALA, Rumph. ; 9. BORASSUS, Linn. ; 10. CORYPHA, Linn.

1. PHOENIX, Linn.

Species 1. *P. sylvestris*, Roxb. ; 2. *P. acaulis*, Buch.-Ham. ; 3. *P. humilis*, Royle ; 4. *P. paludosa*, Roxb. ; 5. *P. dactylifera*, Linn.

1. *Phoenix sylvestris*, Roxb. Wild date palm. Vern. *Khajur*, *khaji*, *salma*, *sendi*, *thakil*, Hind.

An erect palm 30–50 ft. high, with a rounded crown of large greyish green pinnate leaves 7–15 ft. long. Stem covered with the persistent bases of the petioles. The leaves are used for mats and baskets, but the chief importance of the tree lies in the sugary sap which it yields, and which is boiled down into raw sugar or used for the manufacture of fermented liquor. The sap is obtained by cutting a notch into the soft wood at the base of the lowest living leaves and freshening the wound at frequent intervals by paring off a thin slice, the sap exuded being collected in a vessel or section of bamboo (Fig. 371). By the end of the season a large notch is formed, and each successive year the notch is cut on alternate sides of the tree, so that the stem acquires a curious zigzag appearance. Tapping commences in October and ends in March. The wood is used for pegs for tent-pegging.

This palm is common and gregarious in many parts of India, either cultivated or wild. In parts of the sub-Himalayan tract and the Peninsula it occurs gregariously, and apparently wild, on low alluvial land along rivers.

It is accommodating as to soil, but prefers moist alluvial ground provided it is not too heavy and clayey. In such places it regenerates freely from seed, and the young plants are little subject to browsing. So far as is known it does not produce suckers.

Its artificial propagation in Bengal, according to Kanjilal,¹ is carried out by collecting the ripe seeds in May and sowing them in the nursery, which is kept weeded. The seedlings are transplanted in the third rainy season with a spacing of 7 ft. by 9 ft., giving 585 trees to the acre, on ground previously hoed up or ploughed. When the plants are five years old the green upper leaves are tied up like a bouquet, the lower yellow ones being cut away with a sharp knife ; this is repeated annually, the ground being well ploughed meanwhile. In the seventh year, when the stem above ground is about 1½ ft. high, tapping can commence, though it is preferable to wait until the eighth or ninth year, when the stem reaches a height of about 3 ft.

2. *Phoenix acaulis*, Buch.-Ham. Dwarf date palm. Vern. *Thakal*, *jangli khajur*, *pind khajur*, Hind. ; *Thinbaung*, Burm.

A low almost stemless palm with pinnate leaves and a thick bulbous stem densely covered with the persistent bases of the petioles. The leaves are used for mat-making. The fruit is eaten, and a sago is made from the interior of the stem. This palm is common and gregarious in open grassy types of sal forest and in grass-lands, particularly on clayey ground, both in the sub-Himalayan tract and in the Peninsula, also on dry hill slopes. In the outer Himalaya it ascends into the forests of *Pinus longifolia*. It is a common undergrowth species in open *indaing* forest in Burma. The fruits ripen towards the end of the hot season, and are a favourite food of peafowl.

¹ Ind. Forester, xviii (1892), p. 451.

3. *Phoenix humilis*, Royle. Vern. *Khajur*, Hind.

An erect, somewhat variable palm, sometimes attaining a height of 10 ft., with pinnate leaves, the stems densely covered with the bases of the fallen petioles or marked with the scars left by them. Found throughout the greater part of India in hilly country, often on dry ridges, ascending the outer Himalaya to 5,000 ft., and the Nilgiris to 6,000 ft.; also in Burma. It produces root-suckers, particularly if the stem has been damaged by fire or otherwise. The fruit ripens in the hot season. Fig. 58 shows this palm as an undergrowth in forest of *Shorea Tumbuggaia* (see Vol. I, p. 132).

4. *Phoenix paludosa*, Roxb. Vern. *Hintal*, Beng.; *Thinbaung*, Burm.

A densely tufted palm with slender stems 6 to 20 ft. in height or sometimes more, which forms impenetrable thickets in the tidal forests of Bengal, the Andamans, and Burma. The leaves are used for thatching, the smaller stems for walking-sticks and the larger ones for rafters. The fruit ripens during the rainy season or early cold season.

5. *Phoenix dactylifera*, Linn. Date palm. Vern. *Khajur*, *khaji*, Hind.; *Thinbaw thinbaung*, Burm.

A tall tree, attaining a height of 100–120 ft., the stem covered with the persistent bases of the petioles. Leaves pinnate, grey, up to 15 ft. long. Flowers dioecious. The fruits are the well-known dates of commerce, of which there are numerous varieties in cultivation; the leaves are extensively used for mats and bag-like baskets, and the wood of male trees and trees past yielding fruit is used for building and other purposes. The stem yields a sugary sap.

DISTRIBUTION AND HABITAT. The date palm is believed to be indigenous to Mesopotamia and the oases of the Sahara desert. Brandis says it was probably first introduced into India in the eighth century, at the time of the first Mohammedan conquest of Sind, and is now found cultivated and run wild in Sind and the southern Punjab, particularly near Multan and Muzaffargarh. It has also been planted in many other parts of India, chiefly as a result of continued efforts to introduce it during the past half-century. Some of the Punjab dates are of very fair quality, but the tree does not appear to thrive in India except in the drier regions.

In northern Africa and western Asia the date forms a staple article of food, and the tree is extensively cultivated. In these regions it thrives in an arid climate, where it is exposed to great heat in the daytime and often to frost at night. It grows and fruits best, however, with large and continuous supplies of water in the soil, on land which is constantly irrigated. In this connexion an Arab proverb aptly says: 'The date palm, the queen of trees, must have her feet in running water and her head in the burning sky.' In Egypt well irrigation is frequently practised, while round Basra there are immense irrigated plantations which receive copious supplies of water every twelve hours. As regards soil the tree does not appear to be exacting, though it grows best in a sandy loam. On heavy soils prolonged inundation, causing water-logging, is injurious and may kill the trees. In Egypt there are some varieties capable of growing on unirrigated land, and others which grow on low-lying ground subject to frequent inundation. The tree responds readily to manuring.



FIG 371. *Phoenix sylvestris*

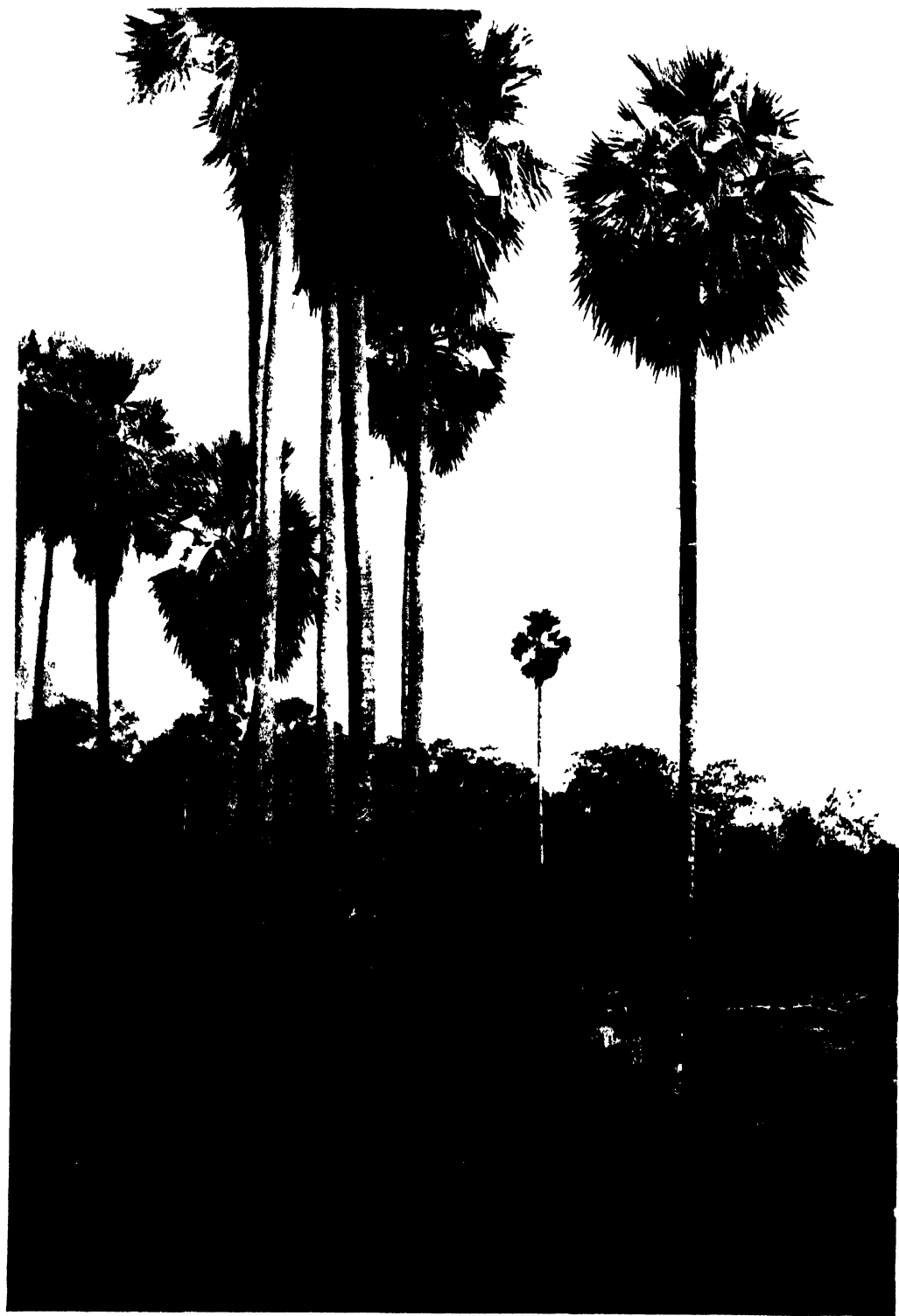


FIG. 372. *Borassus flabellifer*.

CHARACTERS AND REQUIREMENTS. Unlike *Phoenix sylvestris*, the date palm produces suckers in quantity round its base. It resists frost well, and when not flowering and fruiting stands a temperature as low as 20° F. For ripening its fruit, however, it requires dry hot weather. It is a strong light-demander, and will not grow under shade even in youth; young transplants, however, require protection from hot winds. In India it flowers in March–April, and the fruits ripen in September–October. Under favourable conditions the tree commences flowering and fruiting at an age of six to ten years; in Egypt it is said to take ten years to come into full bearing.

PROPAGATION. The tree can be propagated from seed or by planting offsets (suckers). The latter method is preferable to the former; it ensures the propagation of good varieties, while offsets can be taken mainly from female trees, with only so many male plants as are required for pollination. A ratio of three or four male trees to 100 female trees is considered sufficient for purposes of pollination, and this includes a safeguard against loss of male trees. The offsets are usually planted with a spacing of 20 ft. by 20 ft. to 25 ft. by 25 ft. from April to August, freely watered for at least a year, and protected where necessary from hot winds by means of thatch, or, as is the custom in Egypt, with umbrella-like coverings of maize stalks.

POLLINATION. Wind pollination is too uncertain to effect the ripening of the fruit, and artificial pollination has therefore been in vogue since the earliest historical times. The male inflorescence with its spathe is removed as soon as mature, the spathe is slit open, and the flowers are placed in a basket for about twenty-four hours. The cultivator then climbs the female trees on which the spathes have burst and ties sprigs of male flowers among the female flowers, pollination being thus effected. The pollen remains fertile a long time if kept dry, and in some localities it is kept from year to year. Experiments at the Mecca experimental station have shown that it may remain fertile for seven years.

2. ARECA, Linn.

Areca Catechu, Linn. Areca palm, betel-nut palm. Vern. *Supari*, Hind.; *Gua*, Beng.; *Adike*, Kan.; *Kamuga*, Tam.; *Poka-vakka*, Tel.; *Kun*, Burm.

A tall erect palm, 40–80 ft. high, with a straight smooth annulate stem and pinnate leaves, 4–6 in. long. The seeds are the betel-nuts used for chewing and in medicine. This palm is largely cultivated in the moist tropical regions of India and Burma, thriving on deep rich moist loam. Seedlings are raised in shady nurseries and transplanted at an age of two or three years. In Bengal they are planted under the shade of lines of *Erythrina indica*, 12–15 ft. apart, put in as cuttings. When the palms come into bearing the *Erythrina* trees are cut down and a second supply of palm seedlings is planted between the original rows. In Ceylon direct sowing is frequently carried out, the seeds being dibbled in holes about 6–8 ft. apart.

The trees are monoecious, the flowers being unisexual. The fruit is orange or scarlet, 1.5–2 in. long, ovoid; the seed (betel-nut) is about 0.7 in. in diameter. The flowers usually appear from January to March, the fruits ripening from October to January. The usual crop is about 150–300 nuts per tree. Isolated trees may fruit in about seven years, but in plantations fruiting does not usually

take place until the tenth or twelfth year, while the plantation does not come into full bearing until it is twenty to thirty years old. Fruiting is said to continue for about 30-60 years.

3. COCOS, Linn.

Cocos nucifera, Linn. Coco-nut palm. Vern. *Narel*, *nariyal*, Hind. ; *Narikel*, Beng. ; *Narela*, Mar. ; *Thenpinna*, *tengina*, Kan. ; *Tenkaya*, *narikadam*, Tel. ; *Tennai*, *tenkai*, Tam. ; *On*, Burm.

A tall erect palm with a straight or curved stem 40-80 ft. high, with somewhat indistinctly annulate leaf-scars ; base swollen and covered with rootlets. Leaves pinnate, 6-12 ft. long. This palm yields the coco-nut of commerce, largely used as an article of food and as a producer of oil or vegetable fat, which is expressed from the dried kernel known as copra. The fibrous husk of the fruit is used for ropes, mats, &c., the cut flowering stalks are tapped for toddy, and the wood is used for walking-sticks, furniture, and various ornamental purposes as well as for building.

DISTRIBUTION AND HABITAT. The original home of the coco-nut is a matter of some speculation. Some authorities maintain that its original home was in the tropical regions of America, probably on the west coast of Central America, and that it was introduced into the Polynesian islands at an early date, and spread to other islands and mainland coasts. Others maintain that it is a native of the East Indian islands, including Ceylon, and that it spread by means of ocean currents to the Pacific islands. Wherever its original home may have been, it has long been cultivated in the coastal regions of India, Burma, and Ceylon, and is plentiful on the Coco and Nicobar islands in the Bay of Bengal. Germination is not injured by long immersion in sea water, and the fruit is undoubtedly capable of being transported by sea currents, while the coco-nut palm is found on the coasts of uninhabited islands. Nevertheless some authors maintain that it cannot exist permanently in a littoral environment, that it has everywhere been planted by man, that there are no wild coco-nut palms in the Pacific islands, that it does not long survive human neglect, and that from the nature of its fruit it must have originally been a native of a comparatively dry climate, where it could grow to a fairly large size by its own water before having to draw water from the soil. The structure of the fruit, however, might equally well denote that of a littoral species, since halophytes are known to possess xerophytic adaptations such as those exhibited by plants in dry regions. The fact remains that the coco-nut palm thrives best in coastal regions with a warm tropical climate in which the mean temperature does not fall much below 80° F. It is, however, frequently cultivated inland, and thrives and ripens its fruit in Burma as far as lat. 24° or even farther north. In northern India it is occasionally seen as far north as the Gangetic plain. Although the tree thrives in regions of fairly heavy rainfall, excess of moisture in the air is said to be injurious to the formation of fruit, and provided there is sufficient soil moisture to counteract the effect of excessive transpiration a moderately dry climate is said to be preferable to a very moist one. Some fruitful coco-nut districts have rainfalls of only 50 to 70 in. In the dry zone of Upper Burma coco-nut palms thrive on irrigated land with a rainfall of not much over 30 in. On the other hand, coco-nuts are

also grown successfully in regions where the rainfall amounts to 200 in. or more.

The coco-nut palm requires a porous soil with an abundance of soil-moisture. It thrives best on a deep fertile sandy loam along rivers and estuaries. Its roots can endure salt water, but do not require it, and its capacity for thriving on sandy soil along the sea-shore is due largely to the presence of fresh or nearly fresh water not far from the surface. Stiff or water-logged soils and dry porous soils deficient in moisture are unsuitable. The coco-nut palm prefers much lime in the soil, but can flourish in soils with little lime.

LEAF-FORMATION, FLOWERING, AND FRUITING. New leaves arise from the centre of the apical cluster from a bud known as the 'cabbage'. Copeland¹ found, from experiments at the College of Agriculture, Philippines, that leaves took 1½ years from their first appearance until their full development, and that another 1½ years were required for the fruits to mature in their axils. Flowering and fruiting take place throughout the greater part of the year; in India the fruit ordinarily takes 9–12 months to mature. The spadix, which bears both male and female flowers, is about 4–6 ft. long. The fruit is a three-sided obovoid or sub-globose drupe with rounded angles and a fibrous mesocarp. The true seed lies within the hard woody endocarp or shell of the so-called 'nut', which is not a true nut. The seed has a large solid endosperm and a small embryo beneath the largest 'eye' in the shell. Under the most favourable conditions fruiting commences from the fifth to the seventh year, otherwise it commences a good deal later.

SILVICULTURAL CHARACTERS. The coco-nut palm is intolerant of shade, and develops best when fully exposed to the sun; young plants, however, do best under slight shade. It withstands gales very well, sound trees being seldom snapped or uprooted by strong winds; young fruits, however, are sometimes blown down during storms. The root-system consists of a large number of roots radiating outwards to a distance of several yards from the underground portion of the stem and numbers of lateral roots issuing almost at right angles to the main roots. The whole system forms a very firm anchorage.

PESTS AND DISEASES. Bud-rot is an infectious disease which rots the terminal bud and may cause high mortality; diseased trees should be felled and the diseased bud burnt. A stem-bleeding disease has been fully described by Petch,² who has also described a root disease caused by the fungus *Fomes lucidus*.³ Among insect pests the two most serious are *Oryctes rhinoceros*, the rhinoceros beetle, and *Rhynchophorus ferrugineus*, the red beetle, both of which tunnel into the stems and the young tissue at the apex. The former is found in decaying tissues, and there is some doubt whether it is directly injurious. The latter attacks unhealthy trees only, but is more harmful than the rhinoceros beetle.

CULTIVATION. Coco-nuts required for seed purposes should be selected from trees which are prolific bearers. Nuts ripened on the trees are employed, and these are as a rule collected in the hot season. It is not usual to plant

¹ E. B. Copeland, Philippine Agriculturist and Forester, vol. i, No. 3, March 1911.

² T. Petch, Cir. and Agr. Journ. Roy. Bot. Gardens, Ceylon, iv. 22.

³ *Ibid.*, p. 24, March 1910.

the nuts *in situ*, the common practice being first to cause them to germinate and then to plant them out. Various methods of effecting germination are practised, the husk being always left on the nut. In very moist climates the nuts are sometimes hung on a horizontal pole or round the posts of a house and occasionally watered until germination is well advanced, when they are transplanted. Sometimes the nuts, after hanging for a time, are thrown into a well and left to germinate while floating. Some advocate placing the nuts in heaps of ten or twelve and planting them out as soon as they germinate. A commoner practice is to prepare nursery-beds in sandy soil well dug up and to place the nuts on their sides and almost in contact in shallow trenches in the beds, covering them wholly or to about two-thirds of their depth with soil. The seed-beds are kept moist but not saturated. Germination ordinarily takes place in three to six months, and transplanting is carried out as a rule with seedlings 1-2 years old, or occasionally younger, the season of planting being early in the rains. The most usual spacing is 18 ft. by 18 ft. to 30 ft. by 30 ft. The young plants are usually shaded with thatch, and are kept watered in dry weather. Weeding, shallow ploughing, and manuring are now generally considered advisable throughout the life of the plantation, while irrigation may be necessary in dry localities. It has been found advantageous to cultivate leguminous crops under the palms; these are partly dug in for manure and partly grazed. The coco-nut palm responds in a marked degree to cultivation and manuring. In Ceylon it is generally estimated that the cost of formation and tending of a fair-sized coco-nut plantation up to the tenth year amounts to somewhat over £30 per acre, with interest at 8 per cent. and deducting yields in the eighth, ninth, and tenth years.

RATE OF GROWTH AND YIELD. The rate of growth and the yield vary enormously according to the locality and the amount of manuring and cultivation. Mr. A. W. Lushington¹ says that of a large number of plants put down in a garden in Vizagapatam five to six years previously only one or two were beginning to form a definite stem, while by far the greater number had not a semblance of a stem. Other records show much better growth than this. Woodrow mentions trees which reached a height of 60 to 70 ft. in eighteen years in the Bombay Presidency. In Ceylon under the most favourable conditions fruit commences to form in the fifth year, but crops of any size are not produced until the ninth or tenth year, after which there is a rapid increase until the twentieth year, the yield, with careful manuring and cultivation, being maintained until the seventieth year. In native plantations in Ceylon 30 to 40 nuts per tree per year is considered a fair average yield, but 70 to 150 nuts a year are not uncommonly produced. In a well-managed plantation it is estimated that about 3,750 nuts per acre are produced in the fifteenth year, and about 5,000 per acre in the twentieth year. A ton of copra is produced by 4,000-5,000 large nuts, 5,000-8,000 medium nuts, or 8,000-10,000 small nuts.

4. NIPA, Wurmb.

Nipa fruticans, Wurmb. Vern. *Gulga*, *gabna*, *golphal* (fruits), *golpatta* (leaves), Beng.; *Dani*, Burm.

A gregarious palm with numerous large pinnate leaves, 15-30 ft. long,

¹ Ind. Forester, xxxv (1909), p. 152.

arising in tufts from a stout creeping rhizome. This palm is a very characteristic species along tidal estuaries and creeks in the Sundarbans and on the coasts of Chittagong, Burma, the Andamans, the Malay Peninsula and Archipelago, and south to the coast of Queensland; also in the Philippines. It occurs sparingly in Ceylon, but is not found in the Indian Peninsula. It is at times very plentiful, both in the mangrove swamp and in the drier tidal forest behind it, where it occurs in fringes along the banks of creeks.

The leaves are extensively used for thatch and the leaf-stalks are used as fishing floats. The young fruit is edible, and toddy can be obtained from the spathe.

The flowers are monoecious, on a spadix 4–7 ft. long. The fruit is a large head about 1 ft. in diameter, with numerous crowded one-seeded drupes, the seed as large as a hen's egg. The fruits are disseminated by water.

5. CALAMUS, Linn.

This genus contains over 30 Indian species of armed, usually climbing palms, commonly known as canes or rattans, which are characteristic of moist evergreen or swampy ground. Nothing appears to be known regarding the time required for different kinds of canes to reach maturity. In Coorg the time required is believed to be about five years, and in the *ghat* forests a cutting cycle of six years has been adopted in the latest working plan.

6. CARYOTA, Linn.

Caryota urens, Linn. Indian sago palm, fish-tail palm. Vern. *Mari*, Hind.; *Birli*, Mar.; *Baini*, Kan.; *Mhar*, *jilugu*, Tel.; *Konda panna*, Tam.; *Minbaw*, Burm.

An erect palm attaining 40–60 ft. in height under favourable conditions. Leaves bipinnate, of large size, sometimes as much as 20 ft. in length, the ultimate leaflets shaped somewhat like the tail of a fish. The wood is strong and is used for building and other purposes. The inner tissues of the stem yield a starchy substance used as food. The leaves yield a strong fibre known as *kitul*. The flowering peduncles are tapped for liquor.

This handsome palm is distributed throughout the moister forest regions of India, usually in cool, shady valleys, and is often cultivated in gardens. It is said to attain full size in about 10–15 years, and produces flowers for some years afterwards. The tree is monoecious, and the spadices are axillary. The first and longest spadix, 10–12 ft. long, is formed in the upper part of the tree. Subsequent spadices, which are successively of smaller size, are in turn formed lower down, until eventually, when the fruiting is finally over, the tree becomes exhausted and dies.

7. NANNORHOPS, H. Wendl.

Nannorhops Ritchieana, H. Wendl. Syn. *Chamaerops Ritchieana*, Griff. Vern. *Mazari*, trans-Indus; *Kilu*, Salt Range.

A low shrubby palm with much-divided palmate leaves usually arising in tufts from a branched underground rhizome, sometimes from an erect branching stem. The leaves are used for mats, fans, baskets, &c., the petioles are used for ropes, and the seeds are strung in necklaces.

This palm is found in arid regions along the North-West Frontier, in the Peshawar valley, Kohat, Kyber Pass, Salt Range, trans-Indus hills of Sind, and Baluchistan up to 5,000 ft. It grows gregariously, covering considerable stretches of dry stony ground. It can be propagated from seed or from offsets.

8. LICUALA, Rumph.

Licuala peltata, Roxb. Vern. *Kurnd*, Beng. ; *Patti*, Ass. ; *Salu*, Burm.

A palm attaining 10 ft. or more in height, with orbicular peltate deeply partite leaves which are largely used for thatching. Found, often gregariously, in tropical forest and moist ravines in Sikkim, Assam, Chittagong, Burma, and the Andamans. Flowers cold season ; fruits hot season.

9. BORASSUS, Linn.

Borassus flabellifer, Linn. Syn. *B. flabelliformis*, Roxb. Palmyra or toddy palm. Vern. *Tál, tár*, Hind. ; *Tád, tamar*, Mar. ; *Tadi*, Tel. ; *Panam, panai*, Tam. ; *Tan*, Burm. (Fig. 372.)

A tall, erect palm, attaining 70 ft., and under specially favourable circumstances 100 ft. in height, with a black stem bearing narrow annulate leaf-scars ; stems of younger trees covered with dead leaves or the bases of the petioles. Base of stem bearing masses of rootlets. Leaves palmate, multifid, 3-5 ft. in diameter, with somewhat short petioles.

This palm is extensively tapped for toddy, the sweet sap exuding from the cut flowering spadices being fermented into spirit or boiled down into raw sugar. The leaves are used for writing upon and for thatching, mats, fans, &c. The pulp of the fruit, the unripe seeds, and the young seedlings are eaten. The outer hard wood is used for building, particularly for posts and rafters, and the stems hollowed out are used for water-pipes.

DISTRIBUTION AND HABITAT. This palm is believed to be a native of tropical Africa ; it is largely cultivated or has run wild in many parts of India, chiefly south of the Indo-Gangetic plain, and in Burma, particularly in the dry zone, where there are numerous extensive groves. It is also largely cultivated in portions of the Madras and Bombay Presidencies. This palm is essentially a tropical species. It prefers regions of only moderate rainfall, and thrives best on a sandy soil ; it is not suited to very moist climates or stiff soils. Natural seedlings spring up readily, but require protection from grazing.

LEAF-PRODUCTION, FLOWERING, AND FRUITING. The bases of the petioles partially encircle the stem, fitting closely one above another. The immature leaves at the top are pressed tightly together in various stages of development, protecting the growing-point, which is some distance down through the mass of immature leaves. As the leaves become older the base of the petiole splits open longitudinally, leaving a gap of some extent in the centre. Mr. A. W. Lushington¹ has noted that three leaf-bases form a spiral annulation, twelve leaves are developed in the course of a year, and consequently four annulations correspond to a year's growth. Messrs. A. B. Jackson² and J. Donald³ made independent examinations of palmyras and found that each annulation was a quite separate ring, that each ring supported but one leaf,

¹ Ind. Forester, xxxv (1909), p. 148.

² *Ibid.*, p. 394.

³ *Ibid.*, p. 521.

and that the annulations were not spiral. Examinations by Messrs. Hole¹ and McCrie² have confirmed the conclusions of Messrs. Jackson and Donald that each leaf forms a separate and distinct annular scar.

As regards leaf production, Mr. W. McRae has described an experiment carried out at the Central Agricultural Station, Coimbatore, over periods of 6½ and 4½ years in the case of ten and three palmyras respectively, in which the young leaves were marked with zinc labels. This experiment showed that the number of leaves which expanded each year varied from 12 to 16.5 and averaged 14. The mean annual rainfall during the period of the experiment was 25.76 in.

The palmyra palm is dioecious, the male and female flowers being borne on branched spadices on different trees. The fruit is sub-globose, 4–5 in. in diameter, smooth, reddish black when ripe, containing 1–3 hard-shelled seeds (pyrenes) embedded in soft yellowish fibrous pulp. Mr. C. E. C. Fischer³ collected evidence in Malabar, with a moist climate, and Erode, with a dry climate, indicating that fruits are first formed at an age of nineteen years in the former and thirty-five years in the latter.

DISEASES. The most serious disease of the palmyra is that known as bud-rot, caused by the fungus *Pythium palmivorum*, which attacks the bud, eating into the growing-point and eventually killing the tree. Dr. Butler⁴ has described this disease in detail, with measures for controlling it.

PROPAGATION. The palmyra is propagated by direct sowings, owing to the difficulty of transplanting the seedlings.

RATE OF GROWTH. Several years elapse before any upward growth takes place, the underground portion of the stem increasing meanwhile in diameter. Actual instances are on record of the time taken from the sowing of the seed to the commencement of upward growth. Mr. A. W. Lushington⁵ quotes two instances in the Kistna district in 1910: (1) plants nineteen years old were only just beginning to form a stem above ground, (2) seedlings six years old had only a few leaves and no properly developed underground stem.

Mr. J. Donald⁶ recorded in 1910 a case in which seedlings sprung from seed sown in 1892 commenced upward growth when eighteen years old, one or two having commenced a year earlier; subsequent growth was at the rate of 12 to 15 in. a year.

From these recorded instances it would appear to be necessary to add about eighteen to twenty years to the age of a palmyra tree as estimated from its actual rate of growth after upward growth commences. Mr. A. W. Lushington⁷ records an instance of a palmyra grove in Repalli taluk, raised from seed sown in 1829, in which the trees had attained a height of 30 to 36 ft. in 1895, when they were estimated to be one-half to two-thirds grown. Assuming that twenty years were spent in the seedling stage the actual period of upward growth would be forty-six years, and the growth in height would be about 6½ to 8 in. a year.

¹ Ind. Forester, xxxv (1909), p. 632.

² Ibid., xxxvi (1910), p. 575.

³ Ibid., xxxviii (1912), p. 51.

⁴ E. J. Butler, Mem. Dept. Agri. India, Bot. Ser., vol. iii, No. v, September 1910.

⁵ Ind. Forester, xxxvi (1910), p. 364.

⁶ Ibid., xxxvi (1910), p. 688.

⁷ Ibid., xxi (1895), p. 10.

10. CORYPHA, Linn.

Corypha umbraculifera, Linn. Talipot, tali or fan palm. Vern. *Tali*, Kan. ; *Condapana*, Tam.

A large erect palm with a cylindrical annulate stem and large palmate leaves, attaining a height of 80 ft. and a diameter of 2 ft. or more. The starchy pith is converted into flour, the leaves are used for thatching, umbrellas, mats, fans, &c., and the hard seeds are made into beads and buttons.

DISTRIBUTION AND HABITAT. Indigenous to the Andamans and the forests of the Kunta and Honawar *talukas* of North Kanara. Cultivated in the tropical parts of India and in Burma. In the working plan for the Honawar tali palm forests, 1908, Mr. P. E. Aitchison gives a detailed description of the occurrence and working of this palm in the tract in question. Here it occurs on the spurs and slopes of the Western Ghats on light stony soil up to 2,200 ft., thriving best on schist and quartzite on the steep and stony slopes rather than on the lower slopes or the laterite at their base. The rainfall is probably over 200 in. The tops of the hills are clothed with evergreen forest, below which is the tali palm area. The palms are gregarious, being found in patches of a few acres to large belts extending along the whole length of the hill-side, either pure or mixed with *Albizzia stipulata*, *A. odoratissima*, *Lagerstroemia lanceolata*, *Terminalia paniculata*, *Holigarna Arnottiana*, and a few other species. On the lower slopes the forest is deciduous and only occasionally contains full-grown palms, though seedlings are abundant throughout the whole forest.

FLOWERING AND FRUITING. The tali palm is monocarpic, that is, it flowers and fruits but once in its life, on attaining maturity, and then dies. The flowers are bisexual. Flowering takes place from November to January, a huge pyramidal spadix of whitish flowers, 10 to 20 ft. high, appearing at the apex of the tree above the crown of leaves. Meanwhile the leaves commence to wither and droop. After the fruit ripens and falls, that is, in the ensuing hot season, the tree dies and the spadix eventually falls over and decays. The fruit is a globose drupe about 1.5 in. in diameter, with a very hard globose seed. The quantity of seed produced by one tree is very large, averaging, it is said, more than 560 lb. in weight. Sporadic flowering takes place more or less every year, a gregarious flowering taking place at long intervals ; the last general flowering in the Honawar forests is said to have taken place in the early eighties of last century.

NATURAL REPRODUCTION. Natural seedlings appear in great profusion, sporadic flowering being sufficient to ensure natural reproduction in abundance owing to the large quantity of seed produced. The seed is disseminated by the agency of birds, squirrels, and porcupines and by the action of rain, which washes it down the hill-sides.

METHOD OF WORKING. The method of working prescribed in Mr. Aitchison's working plan for the Honawar forests is an adaptation of the selection system. The palms are worked for the flour obtained from the stem ; this substance is yielded after the tree has reached a certain size, when the stem becomes bulbous towards the middle and the inner tissue of the central third of it becomes utilizable. Only palms containing edible pith are exploited,

and for this purpose the trees are divided into four classes: (1) palms containing at least eight head-loads of edible pith (these are usually bulged towards the centre of the stem); (2) full-grown palms with less than eight head-loads of edible pith; (3) half-grown palms; (4) palms which have not yet formed a stem, but which have passed the seedling stage. In fixing the yield the essential point is to know the period occupied from the time when the tree enters class 1 until it flowers and dies. This is not accurately known, but is estimated at twenty years, while the time taken to pass through class 2 is also estimated at twenty years; the yield is fixed by number of trees on this basis.

RATE OF GROWTH. Diameter is no criterion of age. After the stem has reached a certain size it increases no farther in thickness, though it usually swells out in the central portion. Mr. Aitchison has made an estimate of the rate of growth from measurements of palms growing on old *kumri* areas (shifting cultivation). Assuming that the palms started with the regrowth, and estimating their age from that of surrounding trees whose annual rings could be counted, the approximate age of palms of different sizes was found to be as follows: class 1, 70–85 years; class 2, 50–70 years; class 3, 30–50 years; class 4, up to 30 years. Mr. Butterworth¹ describes experiments made since this estimate was formed, which indicate that class 3 and 4 trees put on five new leaves in two years; from this he assumes that a class 2 tree with 160 annulations on the stem shows about sixty-four years' growth from the time when it commenced forming a regular stem above ground, and allowing for the initial period up to this stage he puts the flowering age at about eighty-eight years.

ORDER LXII. GRAMINEAE (tribe Bambuseae)

The bamboos are of such importance in Indian forestry that some account of the silvicultural characters of the tribe as a whole and of the principal members of it must necessarily find a place in this work. It must be admitted, however, that our knowledge of the habits and requirements of the various bamboos is as yet very incomplete, and that a great deal remains to be done in the way of their study. So far experimental work of a silvicultural nature has been confined almost entirely to the commonest of Indian bamboos, *Dendrocalamus strictus*, and the results up to date are given in this introductory note on the bamboos as a whole. Gamble's standard work on this tribe, *The Bambuseae of British India*,² contains not only a comprehensive systematic account of all the species known at the time of its publication, including several new ones, totalling 151, but also gives much information regarding their habits.

DISTRIBUTION AND HABITAT. As Gamble remarks, the distribution of bamboos in India naturally follows the distribution of the rainfall. Temperature is also an important factor in determining the distribution in zones of altitude. Gamble classifies the indigenous distribution of the bamboos described in his work as follows:

¹ Ind. Forester, xli (1915), p. 3.

² Ann. Roy. Bot. Garden, Calcutta, vol. vii, 1896.

Region.	Number of species.
North-western India	7
Central India and Deccan	6
Western Ghats and coast	15
Ceylon	9
Bengal, north-eastern Himalaya and Assam	46
Burma	39
Malaya with lower Tenasserim and the Andamans	29

The Burma region had, however, been insufficiently explored when he published his *Bambuseae*, and when all the bamboos of that region have been described the number of species will probably prove to be greater.

The habitat of the different bamboos varies greatly, but that of each is so well defined that these plants form excellent indicators of different types of forest. For instance, in the Pegu Yoma forests of Burma *Bambusa polymorpha*, which requires a moist fertile well-drained soil, indicates the moist type of upper mixed forest, while *Dendrocalamus strictus* is characteristic of the driest type; *Cephalostachyum pergracile* indicating types midway between the two or verging on the moister types. Again, *Bambusa Tulda* is common on alluvial flats along streams, *Oxytenanthera albociliata* is more typical of low plateaux or hills on sandy or lateritic soil, while the sides of the damper ravines are fringed with the moisture-loving *Dendrocalamus longispathus*; and, lastly, in the dampest valleys of all, where the forest becomes evergreen, *Teinostachyum Helferi* with its long straggling culms forms impenetrable thickets. Similarly, in other localities where various species occur each species can usually be allocated to its particular terrain and type of forest. The commonest Indian bamboo, *Dendrocalamus strictus*, thrives in somewhat open types of mixed deciduous tree forest, or where trees are almost absent, on well-drained light, often stony soil on hill-sides, and extends into drier regions than any other species. The other common bamboo of the Indian Peninsula, *Bambusa arundinacea*, is found on richer and moister soil, often on alluvial ground along the sides of streams. The most important genus of the higher altitudes is *Arundinaria*, comprising nearly thirty species, which are most largely represented in the eastern Himalaya.

As a general rule the bamboos are markedly gregarious. In some cases they form the only second growth on abandoned clearings where shifting cultivation is practised; on such ground they may cover extensive tracts to the exclusion of tree-growth. This is particularly the case with the single-stemmed bamboo, *Melocanna bambusoides*, whose rhizomes show great vitality and power of spreading. In the Arakan hills the effects of shifting cultivation are marked over extensive tracts by the occurrence of pure forests of this bamboo. Regarding a single-stemmed bamboo (*Melocanna* sp.?) in the Karen hills, Brandis¹ noted in 1881 that *taungya* clearings had mostly grown up in bamboos, and that the period allowed for the bamboo forest to grow up before it was cut again varied from seven to fifteen years. In the case of the tufted bamboos this effect of shifting cultivation, in producing large tracts of pure bamboo, is not generally so marked, since the new culms produced after the clump is cut down are smaller and less vigorous for the first few years than in the case of the single-stemmed species. Nevertheless cases are

¹ Suggestions regarding Forest Administration in British Burma, 1881, p. 141.

not uncommon in which the temporary clearing of forest results in a regrowth of pure bamboo of tufted species. Instances of this may be seen in parts of Burma in the case of *Dendrocalamus strictus*, and in the Shan States in the case of *Oxytenanthera albociliata*, which forms the entire regrowth over large areas.

GENERAL CHARACTERISTICS. The bamboos are perennial grasses in which the woody stems (culms) arise from woody rhizomes. In the majority of cases the rhizomes are more or less densely clustered together, and the culms accordingly arise in clumps or tufts, producing the caespitose type of bamboo. In some cases the culms arise at intervals from a long creeping rhizome, either singly, as in *Melocanna*, or in tufts of a few stems together, as in several species of *Phyllostachys*. Between the single-stemmed and the densely clumped forms there are intermediate types forming somewhat open clumps, such as *Dendrocalamus membranaceus* and *Arundinaria jaunsarensis*. The culms are hollow, with walls which vary much in thickness according to species; in some cases, as in *Dendrocalamus strictus* in dry localities, the cavities are small or even absent, solid culms being the result. The culms are divided at intervals, at the nodes, by solid transverse septa. In some species, such as *Thyrsostachys Oliveri*, *T. siamensis*, and *Melocanna bambusoides*, the culms for a considerable distance from the base are devoid of branches, or have only very small branchlets. Some species, for example *Oxytenanthera albociliata* and *Dendrocalamus Hamiltonii*, have large prominent branches, while others, such as *Bambusa arundinacea* and *B. Tulda*, have dense clusters of branchlets at the nodes all the way up the stem, these clusters being almost invariably arranged alternately. In *B. arundinacea* the branchlets are thorny, bearing spinescent buds. In many species aerial roots are produced at the nodes, these occurring in some cases up to about two-thirds the height of the culm and in others only on the lowest few nodes, where they sometimes lengthen and penetrate the soil.

In stature and form the bamboos are very variable. They comprise all degrees of size from the lofty forms of tropical regions, attaining a height of 100 ft. or more, to mere undershrubs, chiefly species of *Arundinaria*, which are found at high altitudes. Most species are erect, but some, like *Teinostachyum Helferi*, are straggling or semi-scandent, while others, like *Dinochloa* spp., are truly scandent, climbing into the crowns of tall trees. Bamboos may be deciduous or evergreen, the former being characteristic of dry and the latter of damp or shady localities. Some species, like *Dendrocalamus strictus*, which are usually deciduous, may be evergreen in damp climates or moist situations, while others, for example *Bambusa polymorpha*, which are ordinarily evergreen, may become deciduous in dry climates and localities and in abnormally dry seasons.

The new culms are produced from the rhizomes in the chief rainy season of the locality in which they grow, appearing above ground in the form of tender pointed cones covered with imbricate sheaths inserted at the nodes. The culms elongate rapidly, reaching full height as a rule in two to four months; the branches develop only after the upward growth of the culm is completed, and the nodal sheaths fall in whole or in part after the culm matures, their period of persistence varying with different species. The number of new culms produced varies greatly with the species and the size and vigour of the clump, while in years of good rainfall the number produced has been observed

to be greater than in years of deficient rainfall. In well-developed vigorous clumps of many arborescent species, ten to twenty new culms a year is not an unusual number, while in some of the shrubby species as many as 50 to 100 or more may be produced under favourable conditions.

Mr. B. B. Osmaston¹ has recorded some interesting observations made in 1917 on the growth of bamboos at Dehra Dun. He notes in the first place that in the case of the various species cultivated there the young culms appeared early in August, that is, more than a month after the beginning of the rainy season, and growth in height was not completed until the end of November. The growth was at first very slow; it quickened gradually for four to six weeks until the culms were some 12 ft. or so in height, when a maximum rate of growth was attained, and this was maintained fairly uniformly for several weeks, after which the rate gradually decreased until the end of November, when growth ceased. Detailed measurements were made of a single new culm in a large clump of *Dendrocalamus giganteus*, these measurements being recorded regularly twice a day, namely at 6 a.m. and 6 p.m., in order to observe the night's growth as well as that of the day. In a few instances measurements were taken at shorter intervals in order to ascertain the effect, if any, on the rate of growth produced by rainfall and a saturated atmosphere or sunshine and a reduced relative humidity. These measurements showed that the growth during the night was usually nearly double of that during the day. This striking difference, however, had apparently nothing to do with light, nor was it directly connected with temperature, for measurements taken at short intervals showed that rapid growth is induced by high relative humidity, irrespective of the time of day or night. Thus measurements taken before and after periods of steady drizzle or rain during the day showed that under these conditions growth was as rapid as it was during the night, whereas in the absence of drizzle and rain during the day the growth was found to slow down, the explanation being that the evaporation which commences with a fall in the relative humidity reduces turgescence, a condition essential for growth. The most rapid growth recorded in a single day was on September 1, when the culm grew nearly 13 in. in twenty-four hours, a rate of growth which was maintained for the next nine days at least, during which period the culm grew 9-18 ft.; it had then attained a height of 23 ft., and measurements, becoming difficult, were discontinued. The culm in question first appeared in the beginning of August, and reached its full height (71 ft.) in the middle of November, so that it took altogether 3½ months to develop, during which time it grew an average of 8 in. in twenty-four hours.

FLOWERING AND FRUITING. The inflorescence, which is made up of spikelets in which the flowers vary in number and arrangement, shows much variation in different species. The fruit is a caryopsis, usually of grain-like form, but sometimes large and fleshy, as in *Melocanna bambusoides*. When flowering takes place the culms as a rule remain in leaf during the early part of the flowering and gradually lose their leaves as it proceeds, although in a few cases the leaves are present throughout its duration. At times some of the culms of a clump flower and die, while the remaining culms do not; this is often observed in the case of *Dendrocalamus strictus*, and may possibly be due

¹ Ind. Forester, xliv (1918), p. 52.

to the fact that the clump has developed from more than one seedling. Some species flower annually without dying, the same clump bearing leafy and flowering culms. This appears to be a common characteristic in the bamboos of America, but is rare in those of India, where it is exemplified in *Arundinaria Wightiana* of the Nilgiris, *Bambusa lineata* of the Andamans, and *Ochlandra Rheedii* of southern India. Kurz says that *Schizostachyum elegantissimum*, a Java species, flowers and dies every third year, reaching a height of 20–25 ft. Bamboos have sometimes been observed to flower without dying, even when flowering takes place at long intervals. This is seen in certain species of *Arundinaria*, and has been observed in the case of imported specimens grown in Europe; in such cases the flowering culms are said to have died, and the rhizomes were much weakened, but with special tending were kept alive and eventually recovered. In a general flowering of *Arundinaria falcata* at Simla in 1916 certain clumps were cut down after flowering; in the following year it was noticed that some of them had died completely, but others had sent up new whippy flowering shoots from the rhizome, showing that the latter still retained some vitality after the first flowering. It is possible, however, that the clump arose from more than one seedling, and that part of it would have flowered in the second year in any case, as was actually observed in other clumps that had not been cut down. Various cases have been recorded in India of bamboos of different species recovering after flowering, and the phenomenon is perhaps not so uncommon as is generally supposed. Such cases, however, appear to be exceptions to the almost universal rule in the case of Indian bamboos in general, namely that these flower at long intervals, and having flowered and fruited they die, reproduction being effected by the numerous seedlings which spring up in the ensuing rainy season and take some years to mature into full-sized clumps.

Some interesting facts have been recorded from time to time in connexion with the flowering of bamboos, but our knowledge of the subject is as yet very incomplete, and the matter well deserves more detailed study. The absence of new culms is generally held to be a reliable sign of prospective flowering in the following year, but systematic observations are required in order to ascertain whether or not this is a universal rule. It has actually been observed not only in the case of bamboos which form clumps, but also in the case of the single-stemmed bamboo, *Melocanna bambusoides*. Offsets taken from clumps which subsequently flowered have themselves been found to flower. Yet a writer in the *Indian Forester*, vol. ii, p. 311, states that in the plantations of *Dendrocalamus giganteus* near Myanaung in the Irrawaddy delta the villagers are in the habit of planting offsets in gaps in the plantation, and that these offsets flower long after the parent clumps, the plantation being thus maintained perpetually. If this be so there may be exceptions to the usual rule in the case of some species or under certain conditions. Cutting down a clump which is about to flower does not prevent flowering; in such a case a profuse mass of flowers appears on the stumps of the cut culms and on the small shoots issuing from the base of the clump. This has been frequently observed in areas cleared for temporary cultivation, particularly in the case of *Bambusa Tulda*, *Dendrocalamus strictus*, and *Cephalostachyum pergracile*. Kurz, however, mentions that in the case of some bamboo plantations it is

customary to cut down all the culms the year before flowering is expected, in order to prevent flowering, and here again there may be exceptions to the general rule. Gamble¹ mentions cases of clumps of *Bambusa Tulda* and *B. nutans* producing flowers before their time when injured by cutting or partial uprooting; it is possible, therefore, that mutilation may, as in the case of fruit trees, stimulate flowering.

Perhaps the most interesting phenomenon relating to the flowering of bamboos is that of gregarious flowering, with which is closely related the question of the life-cycle of the bamboo and the cause of flowering. So far as is known the vast majority of Indian bamboos flower gregariously and die over tracts of varying extent at comparatively long intervals of time. In addition many species flower sporadically, isolated clumps or small groups of clumps flowering and dying here and there. It is impossible always to draw a sharp distinction between gregarious flowering on a small scale and sporadic flowering on a large scale, since the two merge into each other. Similarly, although certain species show a marked tendency to flower gregariously and seldom flower sporadically, while others flower sporadically almost every year and may on occasion also flower gregariously, yet a definite line between the two classes cannot always be drawn. Among species which show a marked tendency towards gregarious flowering at long intervals of time may be mentioned *Bambusa arundinacea*, *B. polymorpha*, *Melocanna bambusoides*, and *Teinostachyum Helferi*. To the other class, namely those which often flower sporadically and may also flower gregariously, belong *Dendrocalamus strictus*, *D. Hamiltonii*, *D. longispathus*, *Cephalostachyum pergracile*, *Bambusa Tulda*, *Oxytenanthera albociliata*, and *Arundinaria falcata*. The seed from sporadically flowering clumps is said to be not always so fertile as that produced at the time of gregarious flowering; this, however, does not appear to be a general rule, since seedlings of several species have been raised from seed obtained from solitary flowering clumps, and natural seedlings have been observed in plenty round such clumps in the forest.

Gregarious flowering usually takes place in three stages: (1) preliminary sporadic flowering, (2) gregarious flowering, and (3) final sporadic flowering of the remaining clumps. The length of each stage may vary considerably, and the first and third stages may be so prolonged as to include the second, which may not be very marked. Gregarious flowering may take place over a comparatively small area or may extend over hundreds of square miles. In many cases it has been observed to commence in one locality and to spread like a wave in a definite direction, taking a few years to extend over the whole flowering area. A general seeding of bamboo attracts to the locality numerous birds, particularly jungle-fowl and pheasants, which as a rule are exceptionally numerous in such areas. The fleshy fruits of *Melocanna bambusoides* similarly attract bison, deer, pig, and other animals. In Burma it has been noticed that in years of gregarious seeding of bamboos rats multiply freely, and when the seeding is over these pests commit great havoc among the neighbouring agricultural crops. For a few years after a general bamboo seeding the forests are littered with a mass of dead culms which are often bound together with herbaceous climbers and form a dense impenetrable tangle, blocking paths

¹ *Bambuseae*, pp. 31 and 33.

and floating-streams. In such places fires of great intensity rage, but while they do severe damage to the tree-growth they are not without their use in helping to clear the ground and make way for natural reproduction.

The factors which determine the life-cycle of bamboos and the occurrence of general flowering are not yet clearly understood. Certain evidence points to the probability that abnormally dry seasons stimulate flowering. Kurz mentions that in two abnormally hot dry seasons in Burma the number of flowering species collected by him was remarkably large; also that in the Calcutta Botanical Gardens an exceptionally large number flowered in 1874, a year of exceptional drought. Other instances of plentiful flowering in hot dry seasons have been recorded from time to time in different forest tracts. The influences which stimulate flowering, however, must act some time beforehand, while gregarious flowering repeatedly occurs in seasons which are not abnormal and in localities where drought is unknown. Further, the flowering of those bamboos which flower annually or at short regular intervals cannot be explained on climatic grounds. But perhaps the strongest evidence against the climatic theory is the fact that bamboos raised artificially by offsets or from seed may flower simultaneously with clumps of the parent stock, or with others raised artificially from the same stock, in different localities under different climatic conditions. Thus *Melocanna bambusoides* flowered in the Bamonpokri plantation, Kurseong, in 1912-13, simultaneously with the general flowering of natural plants in Chittagong. *Dendrocalamus Hamiltonii* planted at Dehra Dun flowered in 1894, simultaneously with a general flowering in the forests of Sikkim. *Arundinaria falcata* planted in Simla flowered freely in 1916, and in the same year this species flowered gregariously in the forests of Jaunsar. MM. A. and C. Rivière¹ mention that in 1867 or 1868 *Arundinaria japonica* flowered almost simultaneously in the Bois de Boulogne, at Sceaux, at Marseilles, and at Hamma in Algiers. These plants were all offsets from a parent plant introduced from Japan in 1850. Again, M. Carrière² says that *Arundinaria falcata* (*A. Falconeri* ?) flowered in 1875-6 in Brittany, Normandy, Angers, Nantes, Algiers, and the garden of the Luxembourg. In the same year it flowered at Fota Island, Co. Cork.³ So far as evidence goes, therefore, although it is not unlikely that hot, dry seasons may stimulate flowering to the extent of accelerating it by a short time, it is difficult to conceive how they can do so except in the case of clumps which have almost reached the end of their life-cycle, and would have flowered before long in any case.

It may be assumed then that the period between successive flowerings of any bamboo represents its physiological life-cycle; it is possible, moreover, that this cycle may be influenced to a slight extent by climatic or other causes, but primarily it is determined by physiological causes inherent in the plant. That this period varies with different species is certain; whether or not it varies for the same species in different localities is not known. Certain species flowering annually or at short intervals have been mentioned. In the case of those species which flower at long intervals it is very difficult to determine accurately, owing to the incompleteness of past records, if the period is constant even in the same locality, but on the analogy of the annual or short-period

¹ Les Bambous.

² Revue Horticole.

³ A. B. Freeman-Mitford, The Bamboo Garden, 1896, p. 8.

species and of other plants like some species of *Strobilanthes*, whose life-cycle is known to be constant, it is reasonable to suppose that the cycle of the long-period bamboos may be at least approximately constant. So far as incomplete records show, the life-cycles of some of the commoner Indian bamboos appear to be approximately as follows: *Arundinaria falcata*, 28–30 years; *Bambusa arundinacea*, 32–34 years; *Dendrocalamus strictus*, between 30 and 40 years; *Melocanna bambusoides*, about 45 years (Chittagong and Arakan). *Bambusa polymorpha* flowered gregariously along the western side of the Pegu Yoma about 1859 and 1860; signs of another general flowering have been in evidence since 1918, so that its life-cycle may prove to be 60 years or a little more.

The extraordinary phenomenon of the gregarious flowering of bamboos at long intervals, with their subsequent death and regeneration from seed, is a source of wonderment to those who have witnessed it, and interesting speculation is possible as to its origin. If the constancy of the life-cycle be accepted as a fact the phenomenon admits of a possible explanation. In the case of species like *Dendrocalamus strictus*, *Cephalostachyum pergracile*, and *Bambusa Tulda*, which frequently flower sporadically, the flowering may be observed in single clumps, or in patches of a few clumps together, which have apparently sprung from a solitary flowering clump of the previous generation, or in small groups of less than an acre, apparently the result of the spread of the seed from one or a few flowering clumps of the previous generation, or in larger groups. And so the progress can be traced from small to large groups of varying size and thence to general flowering over restricted areas and finally to gregarious flowering over considerable tracts of country. This would lead to the conclusion that gregarious flowering is the result of the gradual spread of the species, through successive and more or less constant life-cycles, over a wide area from one or a limited number of original flowering individuals. If this be so, then in the case of those species like *Bambusa polymorpha*, which flower at long intervals with a marked tendency to gregariousness over extensive tracts, the process of taking possession of the ground must have occupied a considerable period of time, and the life-cycles of the various individuals of the crop must have been remarkably constant.

This theory, however, is discounted by the fact that in certain cases of gregarious flowering young plants only a few years old have been found to flower along with the mature clumps. Mr. A. Smythies,¹ describing the gregarious flowering of *Dendrocalamus strictus* in the Chanda district, Central Provinces, says that clumps of all ages flowered—not only mature clumps, but also young plants of six or seven years' growth or even less. Mr. E. V. Ellis² describes a gregarious flowering of *Cephalostachyum pergracile* in Toungoo, Burma, in which young plants, some estimated at about three to six years old and others at about ten years old, had flowered freely. The writer, however, makes an interesting statement with regard to the plants estimated to be about ten years old, namely that the culms had for some reason died, only their bases remaining on the rhizomes, while from dormant buds on these bases numerous 5-foot shoots had come up and flowered. The rhizomes of these young flowering shoots did not appear to be in any way mature. This certainly suggests that it may be easy to confound seedling growth with shoots

¹ Ind. Forester, xxvii (1901), p. 126.

² Ibid., xxxiii (1907), p. 323.

springing from rhizomes which may be connected with those of the mature plants. A fact which I, and no doubt others, have observed in forest of *Bambusa polymorpha* and *Cephalostachyum pergracile* is that a dense growth of whippy shoots often springs up between the clumps, particularly in fire-protected areas, where such growth is encouraged ; these shoots do not consist of seedling growth, since they are found in areas where no recent flowering has taken place, and since they spring from the rhizomes originating from the mature clumps they would naturally be expected to flower when the latter flower. It is reasonable to assume, in the absence of more detailed investigation, that *Dendrocalamus strictus* and other species may under certain conditions similarly produce small shoots of a seedling-like appearance from rhizomes originating from older clumps. It is also possible that suppressed clumps and culms, which have not been able to develop normally, may sometimes be mistaken for seedling growth owing to their small size, although in age they may be equal to the rest of the bamboo crop.

Instances of the undoubted flowering of young bamboo seedlings have been observed from time to time, but these are mere abnormalities. Mr. Sunder Lal Pathak¹ records an instance of the flowering in April 1896 of five seedlings of *Dendrocalamus strictus* raised from seed sown a year previously in a nursery at Pinjour near Kalka ; these died within three or four months of flowering.

GROWTH OF SEEDLINGS AND DEVELOPMENT OF CULMS AND CLUMPS. In the normal caespitose types of bamboos with grain-like seeds, when germination takes place the plumule emerges in the form of a pointed conical bud with sheathing scale-like leaves, which rapidly develops into a thin, wiry stem bearing single foliage leaves arising alternately at the nodes, the bases of the leaves sheathing the stem. Meanwhile fibrous roots develop from the base of the young shoot. The tufted form of the young plant commences to show itself at an early stage. This is effected by the production on the rhizome of successive pointed buds, from which are developed short rhizomes which curve upwards and form aerial shoots. The buds and rhizomes, and the shoots arising from them, become successively larger and larger. The earlier shoots are thin, wiry, and grass-like, but subsequently a time comes when woody culms are produced, which bear some resemblance to the adult culms in form, in the shape of the sheaths, and in other particulars. The transition between the grass-like and the woody culms is gradual ; the latter are at first thin and whip-like, and only at a later stage do culms in any way approaching in size or appearance those of the normal adult clump commence to form. The rate of development of the clump depends very largely, even in the same species, on the conditions under which it has been grown ; this will be referred to below.

A tufted growth may commence to form at an early age. Fig. 373 shows successive stages in the development of a seedling of *Arundinaria falcata*. Fig. 374 shows the germination and early seedling stages of *Dendrocalamus strictus*. In this species the new rhizomes of seedlings take a decided bend downwards before curving upwards to form aerial shoots ; thus the successive shoots, besides being larger than the preceding ones, arise from rhizomes

¹ Ind. Forester, xxv (1899), p. 22.

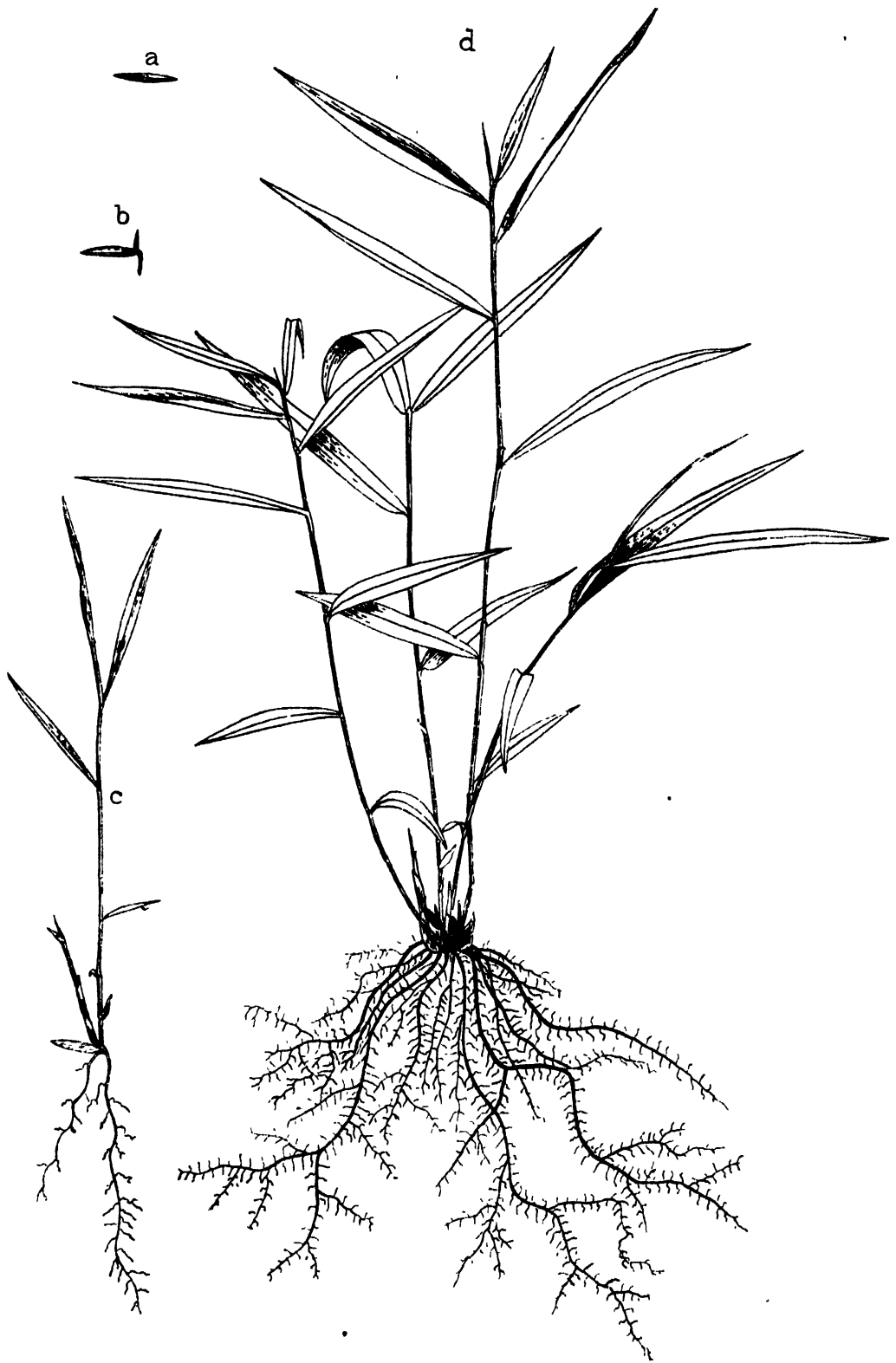


FIG. 373. *Arundinaria falcata*. Seedling $\times \frac{1}{2}$.

a, seed ; b, germinating seed ; c, seedling one month old with seed still attached, showing commencement of formation of tufted stems ; no rhizome yet formed ; d, seedling four months old, end of October.

deeper in the ground. This can be seen in Fig. 376, in which the shoots formed earliest are seen on the left and the one formed latest is seen on the right. In vigorous nursery-grown seedlings of *Dendrocalamus strictus* as many as ten shoots have been counted on seedlings at the end of the first season. Fig. 375 represents a nursery-raised seedling fourteen months old, in August, with six consecutive shoots including the original one. It shows the increase in size of the successive rhizomes and shoots and the manner in which the former push their way deeper and deeper into the ground.

Under unfavourable conditions the shoots of bamboo seedlings may die back for some years in succession before the plant finally establishes itself; this is particularly common in the case of *Dendrocalamus strictus* in dry situations. Even under more or less favourable conditions the first shoot of the seedling may die off at the end of the first season (see Fig. 374, *h*). Under normal conditions the earlier shoots die off sooner or later, on being supplanted by the larger and more vigorous shoots formed subsequently.

The gradual development of the normal clump from the seedling has been carefully observed in the case of *Dendrocalamus strictus*. The formation of clumps in the case of single plants is normally effected by the gradual spread of the plant from the centre outwards by the formation of new rhizomes from which spring new shoots. Under natural conditions, in which the ground may be covered with innumerable seedlings, the formation of clumps is the result of a thinning-out process in which the more vigorous individuals survive. Natural clumps may consist of more than one original seedling.

The time taken to form clumps and to produce normal culms depends greatly on the conditions under which the plants have grown. In the case of artificially raised plants, regularly weeded and watered, whippy culms commence to be produced in the second season, these issuing from amongst a mass of wiry stems previously formed (see Fig. 377). In the third season fair-sized culms, beginning to have the appearance of adult culms, may be formed (Fig. 378). The statement on page 988 shows the rate of development of artificially raised seedlings in some of the experimental plots at Dehra Dun.

In the weeded line sowings the bamboos were large enough to commence working in the sixth year and to yield an average of one to two culms per clump.

Natural seedlings develop much more slowly than those grown artificially under favourable conditions. In January 1911 two plots about half a mile apart were carefully fenced off in the fire-protected sub-Himalayan forests near Kotdwara at the base of the Lansdowne hills in an area where *Dendrocalamus strictus* had recently flowered gregariously, the ground being carpeted with seedlings one year old; a few older seedlings were present, but these have been omitted in the measurements recorded below. The statement on page 990 gives the height and condition of these natural seedlings each year up to an age of eight years.

Dendrocalamus strictus : development of artificially grown seedlings at Dehra Dun.

No.	Conditions under which grown.	Height and other particulars at the end of season.				
		1st season.	2nd season.	3rd season.	4th season.	5th season.
1	Direct sowing, watered and weeded	Maximum 1 ft.	Maximum 8 ft. 6 in. : vigorous	9 ft. 8 in.-12 ft.	Maximum 14 ft. : several stout culms	6th season.
2	Line sowings, irrigated, weeded, thinned	Maximum 4 ft. : vigorous.	Maximum 14 ft.	5 ft.-14 ft. 4 in. Maximum diameter 0.5 in.	Maximum 38 ft. (35 clumps).	
3	Line sowings, irrigated, weeded, unthinned	Maximum 4 ft. : vigorous.	Maximum 6 ft.	2 ft. 3 in.-12 ft. 5 in. : culms thin.	Mean 24 ft. Maximum 30 ft. Mean diameter 2.1 in.	
4	Line sowings, irrigated, unweeded	Maximum 2 ft. 6 in.	Maximum 4 ft. : thin, suppressed	2 ft. 2 in.-11 ft. : few surviving.	Maximum 19 ft.	Maximum 30 ft. (only 3 clumps surviving).
5	Line sowings, unirrigated, weeded	Maximum 3 ft. 6 in.	1 ft. 6 in.-11 ft. : vigorous, with strong culms	Maximum 16 ft. Maximum diameter 1 in. : vigorous	Mean 28 ft. Maximum diameter of new culms 2.1 in. : 5-11 new culms per clump	Mean 32 ft. Maximum 38 ft. Average 8 new culms per clump, maximum diameter 2.2 in.
6	Line sowings, unirrigated, unweeded	Maximum 2 ft. 7 in.	1 ft. 4 in.-5 ft. : thin, suppressed	Maximum 7 ft. 6 in. : condition poor		
7	Line sowings, unirrigated, weeded, raised with field crops	Maximum 2 ft. 8 in.	Maximum 12 ft. : average 4 ft. 6 in.			
8	Nursery transplants, two months old, not watered or weeded after transplanting	Maximum 2 ft. 1 in.	Maximum 5 ft. 2 in.	3 ft. 10 in.-13 ft. 3 in.		
9	Nursery transplants, two months old, not watered or weeded after transplanting	Maximum 3 ft.	Maximum 7 ft.	4 ft. 8 in.-12 ft. 6 in.		
10	Nursery transplants, two months old, not watered or weeded after transplanting	Maximum 1 ft. 5 in.	Maximum 5 ft. 2 in.	3 ft. 2 in.-13 ft.		
11	Nursery transplants, one year old, not watered or weeded after transplanting	..	3 ft.-4 ft.	Maximum 16 ft.	Well-formed clumps, maximum height 9 ft. 9 in. to 21 ft. : maximum diameter 1 in. : largest clump with eight well-developed culms.	

Adjacent.



FIG. 374. *Dendrocalamus strictus*. Seedling.

a, seed $\times \frac{3}{2}$; *b-g*, germination and development of seedling during first season $\frac{1}{2}$; *h*, seedling early in second season $\times \frac{1}{4}$. The original shoot (on right) has died down; the leafy shoot is the new season's first shoot.

Dendrocalamus strictus : development of natural forest seedlings, Kotdwara.

Year.	Age. years.	Height and condition.	
		Plot 1.	Plot 2.
1911-12	2	2-2½ ft.	1½-2½ ft.
1912-13	3	Maximum 4½ ft. : average 3-3½ ft.	2-4 ft.
		Stems wiry and grass-like.	
1913-14	4	Chiefly 4½-5 ft.	Chiefly 3-5 ft.
		A few whippy culms commencing to form : otherwise stems for the most part thin and wiry.	
1914-15	5	Chiefly 7-9 ft.	Chiefly 5-7 ft.
		Small culms formed.	
1915-16	6	Clumps commencing to form. Many seedlings thin and wiry, suppressed by the more vigorous individuals.	
1916-17	7	Dense mass of small clumps. Mean height 10 ft.	Clumps somewhat scattered, height 8-9 ft.
		Diameter chiefly about ½ in., maximum 1½ in.	
1917-18	8	Dense mass of small clumps. Average about 5 culms per clump. Mean height 15 ft. : mean diameter 0.8 in. Best clump with mean height 24 ft., mean diameter 1.4 in., with 7 new culms averaging 28 ft. in height	Average about 4 culms per clump. Mean height 18 ft. : mean height of new year's culms 25 ft. Best clump with 15 old culms of mean height 24 ft. and 6 culms with mean height 28 ft., mean diameter 1.2 in.

Figs. 379 and 380 show the appearance of plot 1 at three years and seven years of age respectively. Judging from the size of the culms and clumps at the last time of recording they might be expected to reach exploitable size at an age of about twelve or thirteen years, that is, in about twice the time required for plants raised artificially and carefully tended.

The season in which new culms are produced appears to be more irregular in the case of young plants than in the case of adult plants. Thus at Dehra Dun seedlings of *Dendrocalamus strictus*, even when not watered, produce new culms at different times from May to October, whereas adult plants produce them normally only in the rainy season from July to September.

Bamboo seedlings in general benefit by a certain amount of protection from the sun, the amount depending on the species and locality. Even in the case of *Dendrocalamus strictus*, which is found naturally in dry hot localities, this early shade is beneficial. In an experiment in the Jubbulpore district in 1910-11, of 200 seedlings of this species transplanted at the commencement of the rains half were planted under cover and the other half in the open ; of the former the whole, and of the latter only 60 per cent., survived. Dense shade and heavy weed-growth, however, are detrimental, and cause wholesale mortality. Bamboo seedlings have many natural enemies. Rats kill them by gnawing through the rhizomes and the base of the stems, squirrels gnaw the shoots, pigs and porcupines dig up young plants in quantity to eat the rhizomes and young shoots, while the seedlings are readily browsed by hares, deer, goats, and cattle.

Hitherto we have dealt mainly with seedlings and young clumps. A clump may be said to have attained maturity when it commences to produce full-sized culms. Thereafter it continues to enlarge by the formation of new branches to the mass of rhizomes, and the number of new culms produced annually continues to increase up to a point. The size of the clump, however,



FIG. 375. *Dendrocalamus strictus*—SEEDLING $\times \frac{1}{4}$
Nursery-raised seedling 14 months old, August,
showing successive shoots, marked a to f

depends more on its vigour, that is, on favourable conditions of soil, climate, &c., than on its age. The older culms in time die off, but the time during which a culm normally survives in the case of different species and under different conditions has not yet been determined. Mr. R. S. Pearson¹ found the following average ratio of new to old culms in clumps of the three species named :

<i>Bambusa arundinacea</i> (W. Coast)	. . .	1 new to 3.42 old
<i>Cephalostachyum pergracile</i> (Burma)	. . .	1 new to 2.93 old
<i>Bambusa polymorpha</i> (Burma)	. . .	1 new to 4.22 old

Unless it is certain, however, that the number of old culms is limited by natural death and not by felling, that is, unless countings are made in areas where no felling has taken place, an estimate based on the ratio of new to old culms might be misleading.

Mr. W. H. Lovegrove² has recorded some observations on the growth of clumps of *Dendrocalamus strictus* which bear on the correct method of working bamboos. He notes that whereas during the development of the clump the rhizomes tend to spread outwards from the centre, with advancing age the clump tends to advance in certain directions only, that is, in the directions most favourable to the development of the rhizomes. On a slope the tendency is to advance up the slope. Injury, such as the cutting of culms on one side of the clump only, causing the death of the rhizomes, or obstructions such as rocks or hard ground, prevent the spread of the clumps in the direction where the injury takes place or the obstruction occurs and cause the clump to extend in another direction. He further traces the cause of the formation of congested clumps to injury round the periphery, and this is further supported by observations recorded later by Mr. B. A. Rebsch.³

The formation of congested clumps, in which the culms are packed tightly together and are often much bent and twisted, is frequently seen under certain conditions, especially in village lands and on the outskirts of the forest where the clumps suffer injury, and in places where the soil is poor, dry, or hardened. It is particularly common in the case of *Dendrocalamus strictus* (see Fig. 381). The correct explanation of this abnormal growth, in most cases at all events, is no doubt the one advanced by Messrs. Lovegrove and Rebsch, namely that the clumps have been reduced to this condition by ill treatment, such as unrestricted cutting round the periphery, browsing of the young shoots round the edge of the clump by cattle, the ground simultaneously becoming hardened, continual removal of the young tender shoots for food, and digging up culms with rhizomes attached for sticks. This constant injury to the periphery of the culm causes the death of the rhizomes, and in time a dense mass of dead rhizomes prevents the living rhizomes from spreading outwards. The latter accordingly develop within the clump, where also the new culms are produced year after year, with the result that congestion takes place and the new culms may bend in all directions in their efforts to penetrate the dense mass of older culms.

In the case of the single-stemmed bamboos, in which the rhizomes instead of being massed together spread laterally to a considerable distance and send up single culms at intervals, the development is abnormal. This, at all events, is the case with *Melocanna bambusoides*, the most important Indian species

¹ Ind. For. Records, vol. iv, pt. v, 1913, p. 18.

² Ind. Forester, xxvi (1900), p. 433.

³ *Ibid.*, xxxvi (1910), p. 202.

and the only species of *Melocanna* whose flowers and fruits are at present known. The fruits are large and fleshy, and the seedlings grow vigorously and produce strong culms from the time of germination; these attain a height of several feet by the end of the first season and reach exploitable size within a few years.

NATURAL REPRODUCTION. Under natural conditions the seed germinates at the commencement of the rainy season, and the ground in the neighbourhood of the seedling clumps becomes carpeted with young seedlings. These spring up and survive in greatest abundance on bare ground, and particularly on newly exposed soil. Where there is a heavy growth of weeds the seedlings are apt to be killed off. Although bamboo seedlings have great power of recovery after being burnt, protection from fire encourages their growth to a remarkable degree, as may be seen in the case of young growth of *Cephalostachyum pergracile* and other species in the moist mixed forests of Burma; if this seedling growth is fire-protected it grows up in the densest masses, choking the natural reproduction of teak and other trees.

Grazing is the greatest enemy of natural reproduction. In some of the heavily grazed forests of the sub-Himalayan tract, where *Dendrocalamus strictus* flowered gregariously from 1908 to 1913, the bamboo has been exterminated by grazing in areas where timely steps were not taken to protect the young growth. Some remarkable instances were noticed in the neighbourhood of Kotdwara. Here the seedlings which sprang up in abundance were in certain areas grazed to such an extent that the ground by January appeared to be devoid of any bamboo seedling growth. Seedlings, however, survived in the middle of the dead bamboo clumps where they were out of reach of cattle, and some of these eventually established themselves. In one of these heavily grazed areas two plots, which have already been alluded to, were fenced off the year seeding took place. Within the plots young bamboo growth established itself in dense masses, whereas outside the fence, where constant grazing took place, the bamboo was exterminated. Fig. 382 shows the edge of one of the protected plots seven years after fencing; the dense growth of young bamboos within the fence, on the left, may be contrasted with the complete absence of bamboo growth outside it, on the right.

In spite of the damage done by grazing, however, bamboo seedlings for a time have great power of recovery. An area near Kotdwara was fenced off two years after the seeding of the bamboo, and in the meantime heavy grazing had kept the ground bare of seedlings; nevertheless after fencing was carried out seedlings sprang up in quantity from the rhizomes which had not been destroyed. Where fencing could not be carried out owing to grazing rights, the expedient was resorted to of overturning the dead bamboo clumps in the rainy season with the aid of elephants; numerous seedlings made their way through the fallen clumps and were thus saved.

ARTIFICIAL REPRODUCTION. Bamboos may be propagated artificially by seed, by division, by offsets, by stem or rhizome cuttings, or by layers.

Propagation by division is usually carried out in the case of the dwarf bamboos, which are easy to handle and transport bodily. This consists in dividing up the mass of rhizomes and transplanting the culms in small clumps of two or three with rhizomes attached; transplanting is best carried out



FIG. 376. *Dendrocalamus strictus*, artificially raised seedling in second season, showing root-system and rhizomes.



FIG. 377. *Dendrocalamus strictus*, artificially raised seedling in second season, showing development of culms. Staff shows feet.



FIG 378 *Dendrocalamus strictus*, artificially raised plants, end of third season, Dehra Dun.

immediately before the growing season commences, and as much earth as possible should be kept round the rhizomes.

The commonest method of propagation by cuttings is that usually termed planting offsets. Culms one year old are cut through with a slanting cut about 3 to 4 ft. from the ground, and the rhizomes to which they are attached are dug up with the roots intact and cut off to a length sufficient to include a well-developed bud. These offsets are planted out sufficiently deep to cover the first two or three nodes, which are usually found close together at the base of the culm. The transplanting of offsets should be carried out immediately before the beginning of the rainy season, and watering should be done in dry weather. A new shoot is produced sometimes in the first year, sometimes not until the second year.

Stem cuttings without rhizomes attached are very uncertain. Vertical stem cuttings are usually taken by cutting the culm down as low as possible, where it joins the rhizome, so as to include the lowest nodes, which tend to produce rootlets. Culms one year old should be employed. In the case of dwarf species the whole culm may be planted, but in the case of the larger bamboos the cutting should be about 2 to 3 ft. long. These cuttings are planted vertically or nearly so, the group of nodes at the base being completely buried. It is preferable to keep cuttings in the nursery until they are well rooted, watering being carried out regularly in dry weather. In the case of some species cuttings, consisting of two nodes with the intervening internode, half buried more or less vertically in manured soil in nursery beds, and well watered, will strike successfully; they require regular watering for some time after transplanting. Another method is to place stem cuttings, consisting of one internode with a node at either end, horizontally in the ground so as almost to cover them with earth, leaving only their upper surface exposed; in that surface a notch may be cut large enough to allow water to enter the hollow internode. Sprouting and rooting eventually takes place at the nodes. This method was tried with several species at Dehra Dun, but the only one which gave much success was *Dendrocalamus Brandisii*, though even with this species the resulting growth was slow.

Rhizome cuttings, that is, sections of fresh living rhizomes of the preceding year about 6 to 12 in. long, containing at least one bud, form a successful means of propagating certain species, particularly *Melocanna bambusoides*, which sprouts readily from such cuttings. These cuttings should be well watered in dry weather.

Some species, such as *Bambusa vulgaris*, are propagated by layers, the culm being partly cut through near the base, bent over and pegged down below the ground. Roots eventually develop and shoots are produced at the nodes: the internodes are then cut through and the resulting plants are separated and planted out.

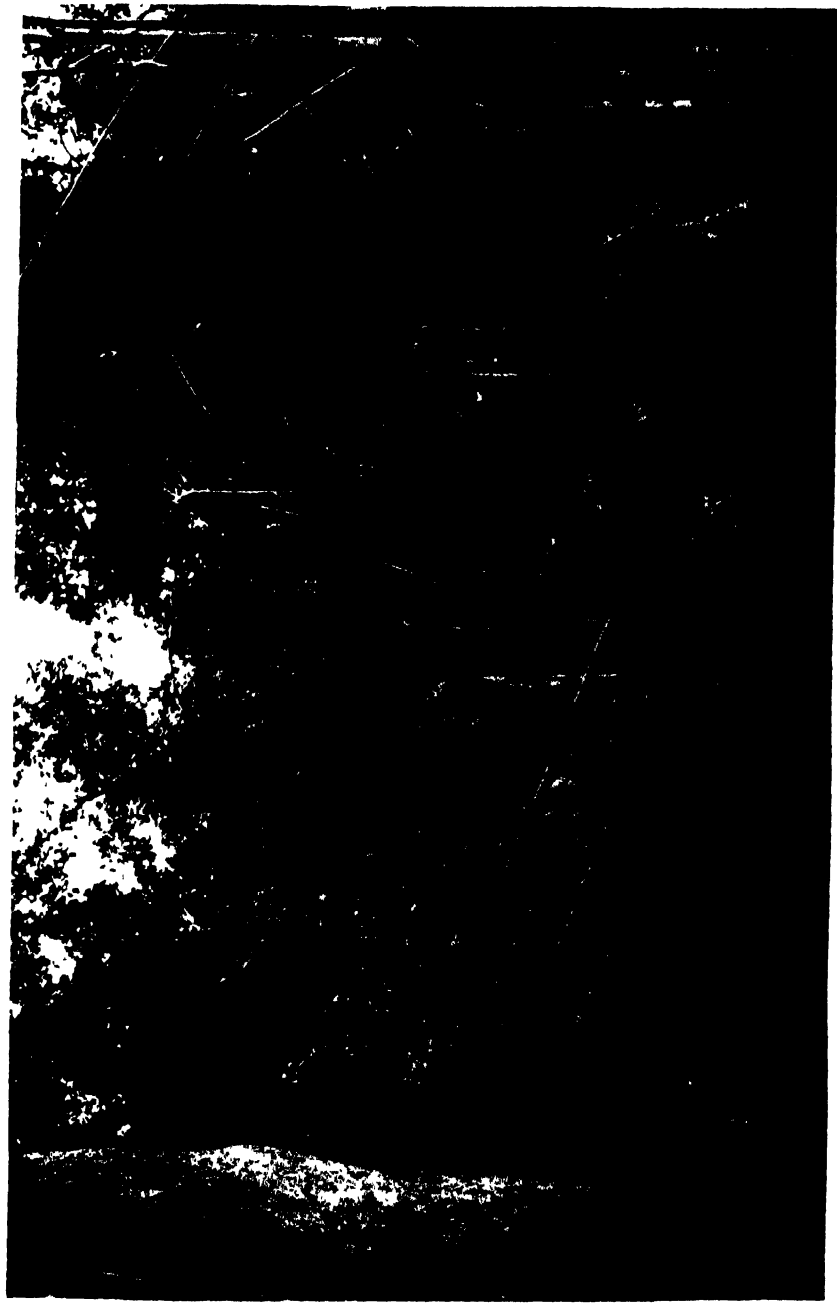
Where bamboos are propagated from cuttings or by other vegetative methods of reproduction some years are required for a normal clump of full-sized culms to form. Under such methods of propagation the resulting clumps are liable to flower when the parent clumps flower, and their life may be short or uncertain. For forest purposes propagation from seed is certainly the most satisfactory method wherever seed is obtainable, but in the case of species

which flower at long intervals it cannot be resorted to regularly. Propagation from seed may be effected either by direct sowing or by transplanting seedlings raised in the nursery.

Direct sowings of *Dendrocalamus strictus* in lines have been carried out experimentally at Dehra Dun with great success. The experimental lines were 10 ft. apart, and were thoroughly dug up to a width of 3 ft. In actual practice the distance between lines would vary with the species of bamboo; for *Dendrocalamus strictus* 18 to 20 ft. would probably suffice. Seed was sown early in June along the centre of each line and lightly covered with earth, one pound of seed sufficing for 600 ft. of line. Subsequent weeding was found to be essential. Where weeding was not carried out the seedlings soon became suppressed and were eventually killed out, whereas weeding accompanied by loosening of the soil along the lines stimulated growth to such an extent that the culms of the fourth year attained a height of 20 to 24 ft. and a diameter of 1.5 to 1.8 in. No watering or irrigation was carried out at any time. It was found advantageous to thin out seedlings, where too crowded, at the end of the first season, to an interval of 3 to 4 ft.; this had a great effect on the growth of the plants left. A second thinning was found to be beneficial about the third or fourth year, after clumps and thick culms had begun to form, the thin whippy shoots being cut out and the clumps separated as far as possible. Fig. 383 shows an unirrigated line sowing after the third rainy season, and Fig. 384 a portion of a line with plants four years old, in which a thinning has recently been carried out. A further series of experiments consisted in raising the same species in unirrigated line sowings with the aid of field crops. The crop employed was the lesser millet, *Eleusine coracana* (vern. *mandwa*), which was sown in the latter half of May and reaped in October, when it was about 4 ft. high. The lines were prepared as before and the bamboo seed was sown early in June. It was found necessary to leave a width of 2 to 3 ft. along the line clear of crops, since the latter if sown continuously over the area tended to suppress the bamboo seedlings. Weeding and thinning were carried out as before, and the results were even better than in ordinary line sowings without field crops, while the expenditure on weeding was considerably less, since the cultivator was responsible for carrying it out while the crops were on the ground. Fig. 385 shows a line in the first season before the crop was reaped.

Irrigated line sowings proved equally successful where weeding was carried out regularly, but so far as the growth of the bamboo and the general results were concerned there was little difference between the irrigated and the unirrigated lines. For moisture-loving species or in dry climates, however, irrigated line sowings would no doubt justify the extra expenditure on irrigation. The water-channels are dug about 1 ft. deep and 1 ft. in mean width, the earth being heaped up in a ridge running along one side of the channel. The seed is sown along the base of the ridge on the side facing the channel. Irrigation by percolation was found to be preferable to flooding in the case of *Dendrocalamus strictus*.

Transplanting from the nursery is frequently resorted to. The seed should be sown in prepared seed-beds shortly after it ripens, or in the case of the hill species in early spring. The seed may be sown either in drills or broadcast,



Procalamus strictus, establishment of natural reproduction. Ko ara. Un
dense mass of natural seedlings of 3 rain seasons (other s of fence



FIG 380 *Dendrocalamus strictus*, establishment of natural reproduction, Kotdwara United Provinces :
(2) same plot after 7 rainy seasons.

the latter being preferable if rats are to be feared, and the seed-beds should be watered and weeded regularly. In the case of most species the plants are ready for final transplanting during the first rainy season. Sometimes they are pricked out in the nursery when a few inches high, but this is not always necessary. Great care is required in planting out, since bamboo seedlings are liable to wither if the roots are exposed to the sun, for which reason the roots should be kept surrounded with earth. In order to guard against failure two or three seedlings are sometimes planted in each pit. In dry localities it may be necessary to water the young plants for some time after transplanting. It is sometimes customary to transfer the seedlings, when two to three months old, from the seed-bed to bamboo baskets, where they are kept until ready for transplanting in the rainy season. The transplanting of natural forest seedlings of *Dendrocalamus strictus* about a foot high has been found to be very successful and cheap. In dry regions it has been found of great advantage to plant out bamboo seedlings under the shade of bushes and low trees; if this is done it may be possible to dispense with watering.

Experiments carried out at Dehra Dun with *Dendrocalamus strictus* showed that transplanting was far less successful in the dry season than in the rainy season; in the former case, although 80 per cent. of the plants survived, the subsequent growth was not good. In these experiments transplanting in the second rainy season was found to be not only more expensive, owing to the large size of the plants, but also less successful than in the first season, a large proportion of the plants dying in the former case. An attempt was also made to transplant in the second rains after cutting the culms down to two nodes from the ground, but this proved to be a failure.

Experiments with *Arundinaria falcata* at Simla showed that good results can be attained by sowing the seed in the nursery in February or March and transplanting in the ensuing rainy season or in February the next year. Care is required not to expose the roots during transplanting.

The formation of bamboo plantations is not unattended with risks. Young plants, both in the nursery and after transplanting, suffer from the depredations of rats, hares, porcupines, pigs, deer, and cattle, and careful fencing may be necessary until the plantation is out of danger. Where successful, bamboo plantations are a source of considerable profit where natural bamboos are absent or insufficient to meet demands. A plantation of *Bambusa arundinacea* near the village of Yeota in the Akola district, Berar, was commenced in 1887 and completed about ten years later. Nursery plants a year old and 1½ to 4 ft. high were planted out 10 ft. by 10 ft., two plants in each pit, and watered for two years after planting. In 1913 the plantation had an area of 25 acres, and contained nearly 3,000 clumps. The total cost of formation and upkeep amounted to Rs. 399 and Rs. 1,032 respectively. The first exploitation was made in 1902-3, and the total number of bamboos extracted up to 1911-12 was 50,053, the cost of exploitation being Rs. 1,163. The gross revenue derived was Rs. 4,875, which gives, after deducting all expenditure, a net return of Rs. 91 per acre in twenty-five years, or Rs. 3-10-0 per acre per annum from the commencement. This does not take into account the value of the land or interest on capital, but as an example of what is possible in a dry region the results are not unfavourable.

EXPLOITATION. The correct method of exploiting bamboos with the view of obtaining the maximum out-turn without impairing the vigour of the clump is one in which our knowledge is as yet far from complete. Methods of working ordinarily resolve themselves into the removal, at definite intervals of years, of either all the old culms, that is, culms more than one year old, or a certain number or proportion of them. The tract to be worked is divided into a number of equiproductive blocks corresponding to the interval of years in question, and the blocks are worked in rotation. When working is carried out on a large scale it is often considered impracticable to supervise any system of cutting out only a portion of the old culms, though this is actually provided for in some working plans, which prescribe the retention of a fixed number of culms per clump, usually eight or ten, and prohibit cutting from any clump unless it contains a larger number of culms than this. Ordinarily no culm less than one year old should be cut, but where young culms are required for basket-manufacture it is customary to permit the removal of a small proportion of these under careful supervision. As regards the rotation, it was formerly the practice to adopt one of two years only, that is, to divide the tract into two blocks and to work them alternately. It has, however, since been ascertained that the clumps deteriorate under such a short rotation, and one of three years is now commonly adopted, though it has by no means been proved that this is not also too short. In some localities longer rotations, up to six years, are in force.

The height at which the culms should be cut is another matter of importance. Bamboo cutters, unless controlled, are apt to cut them several feet above ground, and in time the clump becomes choked up with dead and dying lengths of culms which render cutting difficult. In the Siwaliks systematic thinnings had at one time to be carried out for a series of years, at considerable expense, in order to remove the masses of culm remnants from within the clumps. On the other hand, it has been held by some that cutting low down near ground-level is injurious in that culms when cut die down at the rate of one internode a year, and hence if low cutting is carried out the rhizomes quickly die. The experiments mentioned below have shown that the view that cut culms die at the rate of one internode a year is not correct; that they die down in many cases is true, but the rate of dying appears to depend mainly on the vigour of the culm, some dying down rapidly and others not dying at all for a few years at least. Nevertheless as the point is still in doubt it is now usually customary to prescribe cutting at a definite height, say between 1 and 2 ft. from the base, thus effecting a compromise between high and low cutting. The judicious thinning out of dead culm remnants and twisted culms from within the clumps has been found most beneficial in the case of *Dendrocalamus strictus* in the Siwalik hills, where also the use of the saw in preference to the axe has been found to minimize the damage to the stumps of felled culms. Nevertheless, the drastic removal of quantities of culm remnants from within a clump may do more harm than good. Mr. A. Wimbush¹ records a case in South Malabar of an experimental cutting out of culms and dead lengths of culms cut high in former fellings, the species being *Bambusa arundinacea*. From four clumps 99 green bamboos and 109 dead lengths were

¹ Ind. Forester, xxxix (1913), p. 155.



FIG. 381. *Dendrocalamus strictus*, congested clump; note dead rhizomes on periphery.

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FIG. 381. *Dendrocalamus strictus*, congested clump; note dead rhizomes on periphery.



FIG 382. *Dendrocalamus strictus*, natural reproduction 7 years old, showing adverse effect of grazing, Kotdwara, United Provinces: portion to left of fence protected from grazing, with dense young growth of bamboos about 8 ft high, portion to right open to grazing and devoid of young bamboos.

cut, leaving 35 sound culms, or about nine in each clump, evenly scattered through the clump. The result was that every culm was blown over during the succeeding monsoon and was either broken or bent over until it leant against an adjoining clump. In three clumps examined next season two had produced no new culms and the third had sent up two very thin culms, both of which had been broken. *Bambusa arundinacea*, however, is a species in which it is hardly possible to test satisfactorily the effect of judicious thinnings. The dense mass of interlacing thorny branchlets renders it difficult to remove individual culms so as to leave the remainder moderately and evenly spaced, while the culms of this species are soft and weak for their size and are easily bent or broken by wind. Fig. 386 shows the effect of a heavy thinning in the case of this species.

Mr. W. H. Lovegrove,¹ in describing his observations on the growth of *Dendrocalamus strictus* in the submontane forests east of the Ganges, which have been alluded to above, concludes (a) that a clump should be encouraged to grow in the directions chosen by itself, which can be determined by observing where the youngest culms are; (b) that the culms should not be cut over the whole periphery of a clump; and (c) that care should be taken not to clean out too large areas in a clump, thereby causing the accumulation of a large mass of dead rhizomes.

Much experimental work of a systematic kind remains to be done in order to study the development and growth of the various important species and to ascertain the best method of working them. In this connexion a series of experiments was commenced by me in 1910-11, the species dealt with being *Dendrocalamus strictus*. Two experimental plots were laid out, one in a somewhat dry locality (rainfall 50 in.) at Ranipur in the Saharanpur Siwaliks, dealing with 57 clumps, and one in a fairly moist locality (rainfall probably about 70 in.) near Kotdwara, in the submontane forests of the United Provinces, dealing with 98 clumps. The main objects of the experiments were to ascertain the effect (1) of cutting culms at different heights above ground, (2) of working under different rotations, and (3) of cutting all or only a portion of the old culms (that is, culms more than one year old) at one time. These experiments have been continued regularly since their commencement, Mr. Marsden taking over control of them in 1915. Although the experiments have not yet been in progress long enough to produce final and definite conclusions on all points, the tentative conclusions arrived at after eight years have been summarized thus by Mr. Marsden: ²

' 1. Annual working, whether cutting high or cutting low, whether removing all old culms or only half of them, leads to more or less rapid reduction in size of clump, in number of new shoots, and in girth of culms.

' 2. When all the culms except those of the current year are cut, the clump deteriorates. This is true for 1-year, 2-year, and 3-year rotations, and for cutting at a height of one node, three nodes, or five nodes. When the rotation is four years, the result is not so obvious.

' 3. When the rotation is one year and only half the number of old culms is cut, the results are better than when all old culms are cut. Height of cutting

¹ Ind. Forester, xxvi (1900), p. 433.

² *Ibid.*, xlv (1918), p. 147. It should be noted that the conclusions refer only to *Dendrocalamus strictus* in the United Provinces.

makes no difference. Of fifteen clumps treated thus, only two were in good condition, and this method cannot be recommended. When only half the old culms were cut, the clumps under a 2-year rotation were in much better condition than those under a year rotation.

'4. Whatever the rotation, some old culms should be left. Old culms are wanted both for the mechanical support of new shoots and to maintain the rhizomes in full vigour.

'5. The effect of difference in height of cutting upon the health of the clump is either nil, or so slight as to be negligible. Cutting high produces a number of twigs at the top of the stumps which impedes working.

'Production of new shoots is not affected by height of cutting. But removing half the old culms gives more shoots than clear-felling all old culms, and 2-year rotation more than 1-year rotation. Of the methods under experiment, most new shoots were yielded by the clumps worked under a 2-year rotation when half of the number of old culms were felled. Felling all the old culms fails to produce many new shoots even when the rotation is four years. But a 3-year rotation, some of the old culms being left standing, would probably give better results than a 2-year rotation.

'Clear-felling all culms, including shoots of the current year, nearly, but not quite, kills the clump. After four rains the clumps are beginning to look up again, and shoots $\frac{1}{2}$ in. thick to arise. Repeating the complete cutting of all culms without exception for two consecutive years would here probably kill most clumps.

' General Remarks.

'To work these bamboos economically, it would appear that in every clump some old culms must be left standing. A 2-year rotation leaving half the old culms may be better than a 3-year rotation felling all the old culms. But a 3-year rotation leaving some old culms would very likely be better still.

'A system of working bamboos may be based on the size of the clump, on the number of new shoots produced, or on a minimum number of old culms to be left standing. But the system must be one which admits of easy check. If a proportion of the old culms is laid down as the standard, it is in practice difficult to check whether too many culms have been felled or not. If the Punjab this method has been adopted, and I understand that it cannot be strictly enforced though it is said to work well in practice. Similarly, any rule prescribing a minimum number of old culms to be left based on the number of new shoots is practically unworkable.

'It would be simpler to fix a minimum number of old, sound culms at least one inch thick, which must be left in each clump. But clumps vary in size. So the average size of clump in the locality must be ascertained. In the average clump contains 20 old culms, and the rotation is three years, a minimum of seven old culms per clump might be fixed.

'Another problem is the distribution within the clump of the culms left standing. Clear-felling part of a clump is liable to kill that part of the clump ; so the culms left standing should be distributed evenly over the clump.

'While a fully-stocked clump produces more shoots than a severely worked clump, there seems ground for the belief that if kept in an open condition more shoots will arise than if allowed to become congested. Loosening the earth and heaping it up round the base of a clump is likely to stimulate the sprouting of new buds.

'Where bamboos have been worked continuously for years, it might be highly beneficial to give the clumps a period of rest for three or four years before introducing a new method of treatment.'

ERADICATION OR CONTROL OF BAMBOO GROWTH. In some localities bamboo growth is so rampant as to interfere with the reproduction or development of valuable tree species, and measures have to be adopted to keep the bamboo

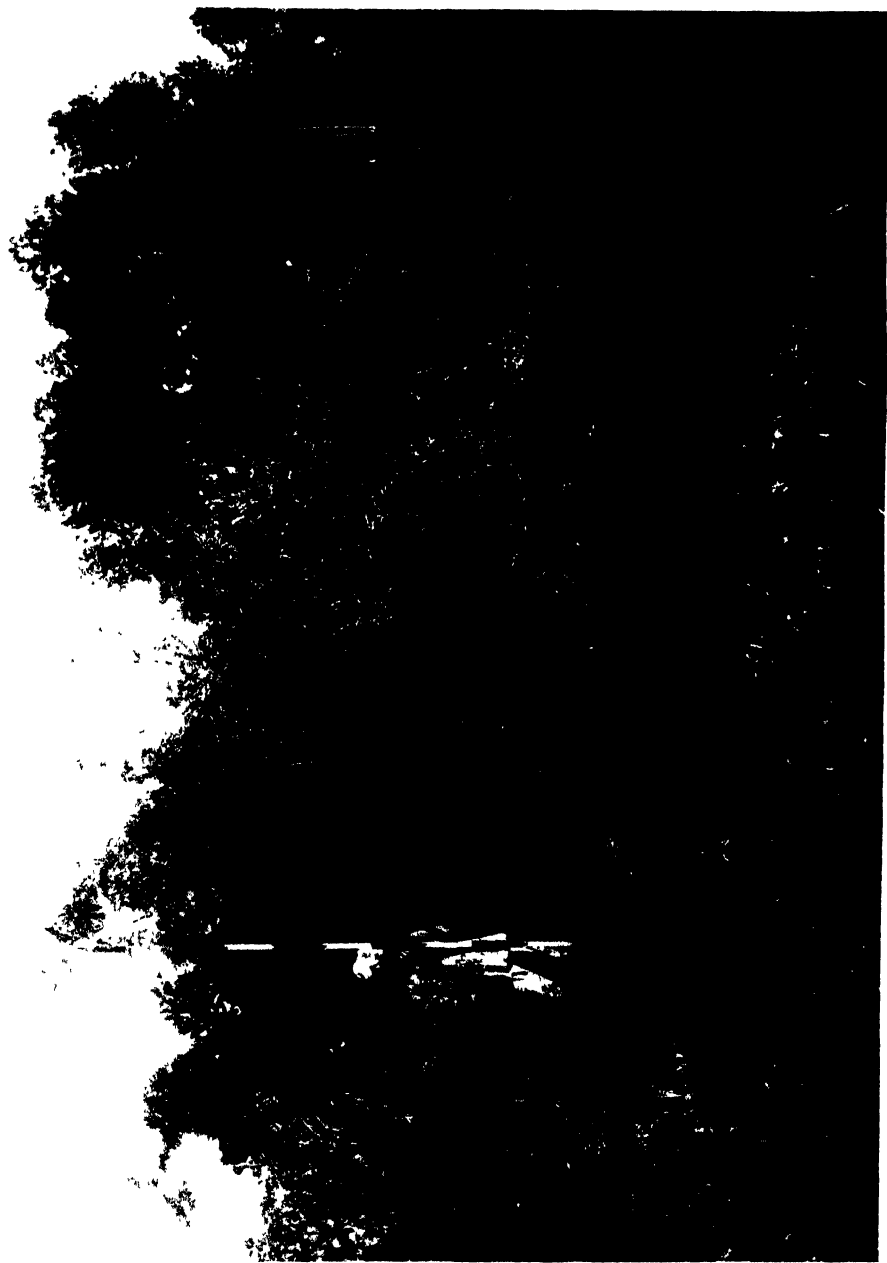


FIG. 383 *Dendrocalamus strictus*, unirrigated weeded line sowing, end of third season, Dehra Dun.

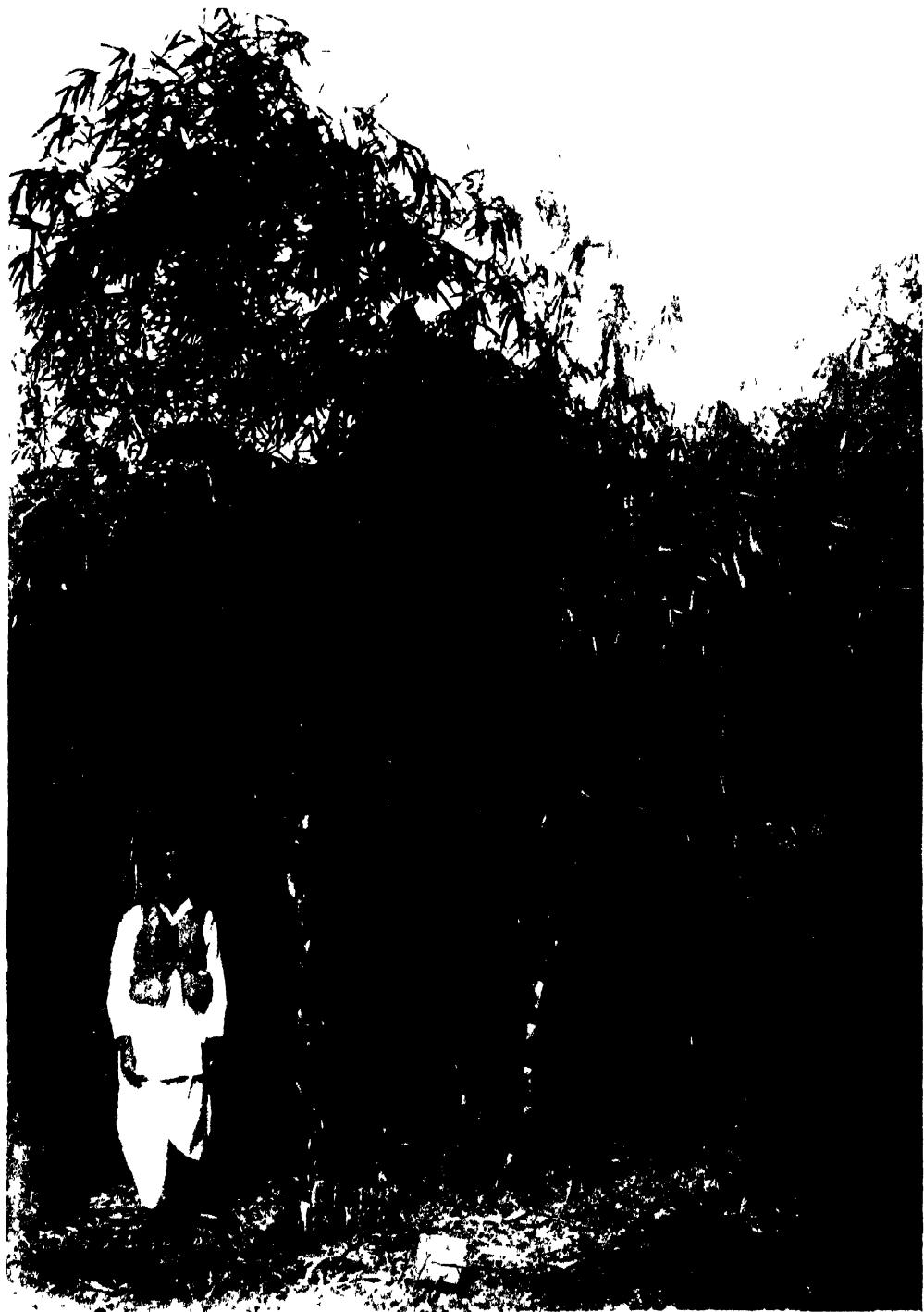


FIG. 384 *Dendrocalamus strictus*, irrigated weeded line sowing 4 years old, Dehra Dun . clumps recently thinned by removal of all thin culms.

in check. This can be done most effectively at the time of flowering or seeding ; failing this, established clumps have to be dealt with.

The species whose eradication over limited areas can be most easily carried out is *Melocanna bambusoides*, whose large fruits can be collected off the ground when they fall ; this is done by *taungya*-cutters in the Arakan hills, in order to obtain areas free from bamboo in which to practise shifting cultivation. Otherwise experiment has shown in the case of this species that by cutting the bamboo in April, when the fruits are almost ripe, the bamboos are killed and the great majority of the fruits are destroyed ; if the bamboo is cut in the cold season when about to flower it flowers from dwarf shoots next year. As regards other species, experiments carried out in recent years in Burma have shown that when gregarious flowering takes place, burning early in the season has little effect. The most effective plan is to fire-protect the area until the seed has fallen and burn late in the hot season in order to cause as intense a fire as possible ; even so only a portion of the seed is destroyed, and seedling growth appears in the rainy season. Subsequent burning tends to reduce the density of the young growth, but does not destroy it. The admission of grazing for a few years after seeding further tends to keep the young bamboo growth in check, for as long as there are bamboo seedlings on the ground it is found that cattle prefer them and will not eat tree seedlings: Where gregarious seeding has taken place and the young bamboo crop is allowed to establish itself unchecked for two or three years, fire alone has little effect on it, while the alternative of cutting and burning, which has to be repeated as a rule, is costly. Fire-protection has the effect of aggravating greatly the density of the young bamboo growth, and it is usually impossible to produce any effect on it except by cutting followed by burning.

The eradication of mature bamboo clumps is usually a tedious operation. The complete cutting of all the culms of a clump results, in the ensuing rainy season, in the production of thin whippy shoots, and if no further cutting is carried out the culms produced in successive years become larger until the clump again reaches its normal state. A single complete cutting, therefore, though it may afford a temporary opening for the establishment of tree species, is not sufficient to eradicate the bamboo. If, however, the cutting of the new culms is repeated at intervals of one or two years it has been found that the clump is so weakened as to die after a short period. Where shifting cultivation is practised in Burma, the usual custom is to cut down the bamboos, pile them on the stumps, and burn them ; this kills a certain number of the clumps, but not all, though if the operation is repeated for another year or at most two years, this usually suffices to eradicate the bamboo. On fire-lines, where bamboos are cut and burnt annually, they are as a rule killed out within three years. Experiments in Katha, Upper Burma, have shown that *Dendrocalamus Hamiltonii* can be killed by one cutting and burning if the cut culms are heaped on the bamboo stumps and burnt, and the young shoots in the following rains are broken off as they appear.

An experiment was commenced in the forests of the Tharrawaddy district of Burma in 1893 with the object of ascertaining if the annual cutting out of the new year's culms would kill the clump within a reasonable time. The species experimented with were *Bambusa polymorpha* and *Cephalostachyum*

pergracile. Two areas were set aside, one in the Kônbin and the other in the Bawbin forest, and the cutting out of the new year's culms was carried out annually for ten years, the older culms being left; during this period an average of two new culms per clump were cut out annually, and at the end of the ten years' period the clumps were found not to have been perceptibly weakened, though the cover was somewhat lightened.

A few years ago an experiment was carried out in Kollegal, Madras, to ascertain, by clear-felling an acre of bamboo forest each month of the year, if there was any particular period of the year in which clearing assists in keeping down the bamboos. The experiment gave no definite results, it being found that the regrowth was more or less the same in each case.

Genera 1. *ARUNDINARIA*, Michaux; 2. *BAMBUSA*, Schreber; 3. *THYRSOSTACHYS*, Gamble; 4. *GIGANTOCHLOA*, Kurz; 5. *OXYTENANTHERA*, Munro; 6. *DENDROCALAMUS*, Nees; 7. *CEPHALOSTACHYUM*, Munro; 8. *MELOCANNA*, Trin.

1. *ARUNDINARIA*, Michaux.

Erect, sometimes climbing, shrubby bamboos, in India almost exclusively hill species, often gregarious and forming an undergrowth in the forest.

Species 1. *A. Wightiana*, Nees; 2. *A. racemosa*, Munro; 3. *A. falcata*, Nees; 4. *A. spathiflora*, Trin.

1. *Arundinaria Wightiana*, Nees.

Hills of southern India, especially the Nilgiris, where it forms a gregarious undergrowth in the evergreen *sholas*. Culms 6–10 ft. high. Flowers annually.

2. *Arundinaria racemosa*, Munro. Vern. *Maling*, Nep.

Common in the eastern Himalaya at 6,000–10,000 ft., growing gregariously, and much used for pony fodder. Gamble notes that there may be two species: (1) the larger low-level form, which has never been known to flower, and (2) the small high-level form of which flowers were collected in 1857 and 1887 to 1890. This bamboo forms a very dense undergrowth, impeding the natural reproduction of tree species (Fig. 387). When fires occur in such areas a fierce conflagration results, causing destruction to the tree growth (Fig. 388).

3. *Arundinaria falcata*, Nees. Vern. *Ringal*, Jaunsar.

The low-level ringal of the western Himalaya, used for basket-work, fishing-rods, &c. Forms clumps containing a large number of culms, often more than 100 in a clump; culms 6–10 ft. high. This bamboo grows gregariously, forming an undergrowth in forests of oak, deodar, and other trees, usually in moist shady situations, at 4,000–7,000 ft. It flowers both sporadically and gregariously. General flowering has been recorded as follows:

1858. Simla.

1886. Jaunsar and Tehri Garhwal.

1916. Simla, Mussoorie, Jaunsar.

In Simla, 1916, the flower-buds became visible in April, the flowers opened early in July, and the seed ripened and fell in November. Under natural conditions the seed lies on the ground until the commencement of the following rainy season, in June–July, when it germinates, and seedlings may be found in quantity around the parent clumps and in places where the seed has been washed by rain. Fig. 373 shows the seedling and the manner in which the clump forms (see p. 986).

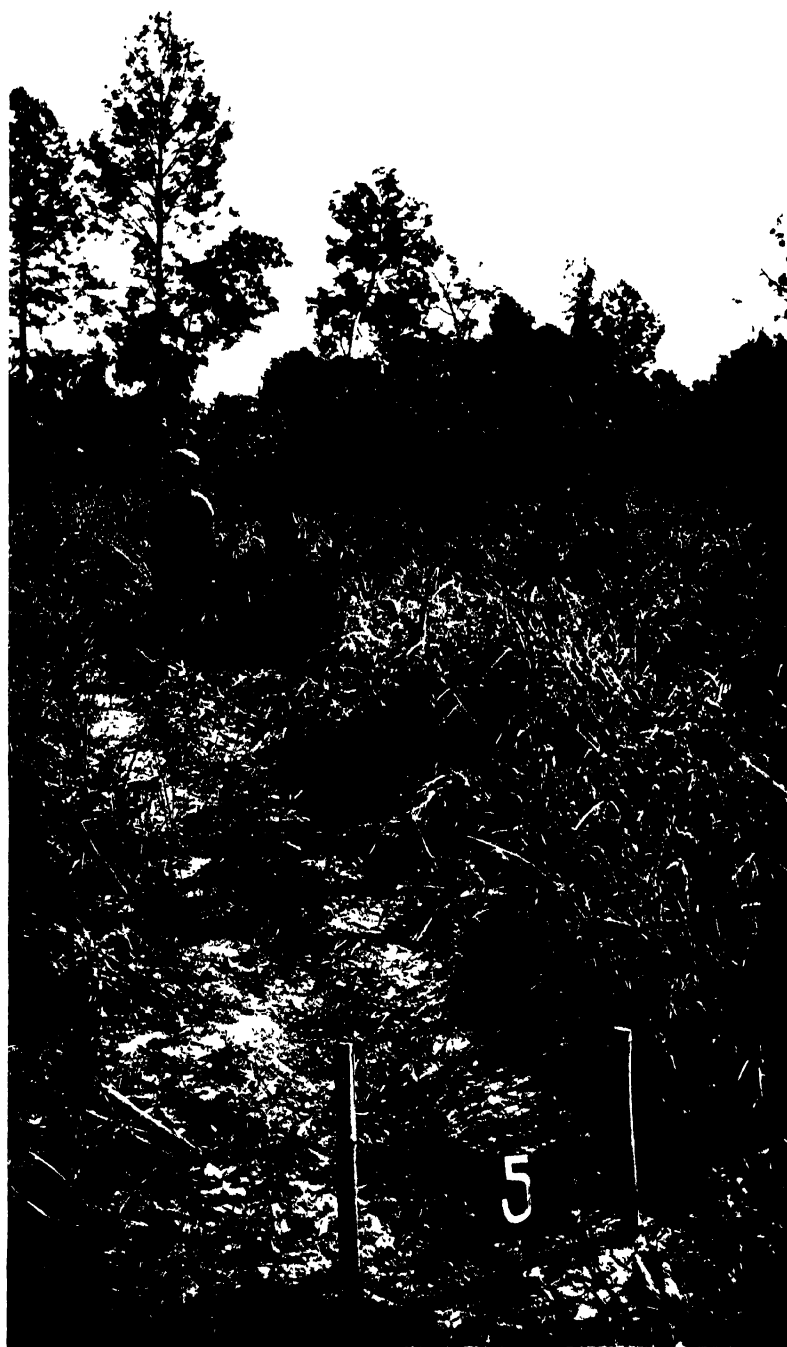


FIG. 385 *Dendrocalamus strictus*, weeded line sowing with field crops, end of first rainy season, Dehra Dun.



FIG 386 *Bambusa arundinacea*, effect of heavy thinning of clump four years previously, Tinnevely, Madras

4. *Arundinaria spathiflora*, Trin. Vern. *Ringal*, Jaunsar.

The high level ringal of the western Himalaya. Grows gregariously at 7,000–9,000 ft. from the Sutlej to Nepal, forming an undergrowth in forests of oak, deodar, spruce, silver fir, and other trees, usually in moist shady situations. Culms 12–20 ft. high, in definite clumps. Flowers sporadically and gregariously. There was a general flowering in Jaunsar and Tehri-Garhwal in 1882, and in 1898–9 the culms were reported to be about 10 ft. high, and not yet full sized, indicating that the growth is slow.¹

2. *BAMBUSA*, Schreber.

Species 1. *B. Tulda*, Roxb. ; 2. *B. nutans*, Wall. ; 3. *B. burmanica*, Gamble ; 4. *B. polymorpha*, Munro ; 5. *B. arundinacea*, Willd.

1. *Bambusa Tulda*, Roxb. Vern. *Peka*, Hind. ; *Tulda*, *mitenga*, *jowa*, *kiranti*, Beng. ; *Wamuna*, *bijuli*, Ass. ; *Thaikwa*, Burm. (Fig. 389.)

A thick-walled caespitose evergreen or deciduous bamboo, attaining 70 ft. in height under favourable conditions, branching freely from nearly all the nodes, the branches from the lower nodes being thin and more or less horizontal. A useful species for building, owing to its strong culms ; also used for basket-work, mats, &c. A native of Bengal, Assam, Northern Circars, Chittagong, and Burma. Frequently cultivated, especially in Bengal. In its wild state it is characteristically gregarious. In Burma it is frequent on flat alluvial land along streams in the mixed deciduous forests and along the banks of dry water-courses.

It often flowers sporadically or in small groups, while occasional gregarious flowering takes place, of which the following cases have been recorded :

Burma. About 1865. Tharrawaddy.

1903–5. Tharrawaddy : fairly extensive flowering in single clumps or groups of varying extent.

1908. Prome.

1911. Gangaw.

1913. Toungoo, Zigôn, Rangoon.

1914. Southern Toungoo, Pegu, Prome, Zigôn, Tharrawaddy, Rangoon, Henzada, Yaw.

1915. Northern Toungoo, Shwegyin, Prome, Zigôn.

1916. Southern Shan States.

Assam. 1889. Locality not stated.

1910. Sylhet.

Bengal. 1867–8, 1872, 1884. Locality not stated.

1876, 1886. Chittagong.

Brandis² records various flowering years, but it is not certain if these refer to gregarious flowering or to years in which flowers were collected.

2. *Bambusa nutans*, Wall.

A fairly thick-walled species much resembling the last, but the culms are not so densely clustered. Attains 40 ft. Frequently cultivated in the sub-Himalayan tract ; Gamble says that it is doubtful if it is really wild west of

¹ F. Gleadow, Forest School Tour in Jaunsar 1898–9, p. 32.

² Ind. Forester, xxv (1899), p. 12.

the Sarda river, and that it is found in the Sikkim hills up to 5,000 ft. Its culms are strong and useful.

3. **Bambusa burmanica**, Gamble. Vern. *Thaikwa*, *thaikwagyi*, Burm.

A large thick-walled bamboo attaining 50–60 ft. in height and 4 in. in diameter, somewhat resembling *B. Tulda*, but growing in more open clumps. Indigenous to Upper Burma, on dry hill-slopes. Plants have been raised in considerable quantity at Dehra Dun from seed received from Burma, and have succeeded well. There is a plantation of this species at Lachiwala, near Dehra Dun; here the culms were all killed down in the abnormal frost of 1905, but the rhizomes were not injured, and in a few years the clumps had completely recovered by the production of new culms. This bamboo is a useful one, with strong culms.

4. **Bambusa polymorpha** Munro. Vern. *Kyathaungwa*, Burm. (Fig. 390.)

A large, handsome tufted bamboo with tall, clean culms, attaining a height of 80–90 ft. and a diameter of 6 in., evergreen, or in dry localities and seasons partially deciduous. This bamboo, which has moderately thick walls and large cavities, is probably more extensively used for building purposes than any other species in Burma. It is a promising source of supply of paper-pulp. In Burma it is abundant throughout the moister types of upper mixed deciduous forest in the Pegu Yoma, particularly on the lower slopes and in well-drained valleys, where it flourishes best and reaches its largest dimensions on deep moist fertile loam. It is not found in the driest parts of the range. It occurs also in Martaban in the Salween valley and locally in other parts of Burma, for instance in the Thaungyin drainage in Tenasserim and in a few places in the Yaw drainage in Upper Burma; it extends into eastern Bengal and Sylhet.

Silviculturally this is probably the most important bamboo in the Pegu Yoma forests, where it is commonly associated with teak and is an indicator of deep, rich, well-drained soil on which the teak reaches its best development. On such soil it is gregarious to a marked degree, but a frequent companion and a species of almost equal importance is *Cephalostachyum pergracile*, which, however, also extends into forests of a somewhat drier type than those in which *Bambusa polymorpha* is characteristically found. The large size and vigorous growth of the latter make it a serious competitor of the teak.

This species flowers at long intervals, and the flowering is remarkably gregarious. Until recent years sporadic flowering has been rarely recorded, but occasional flowering clumps have been observed. In 1899 three clumps are reported to have flowered in the Pegu forests. I found two flowering clumps in the Tharrawaddy forests in February 1903. It flowered sporadically in 1913 in Minbu, Thayetmyo, and Prome, while in Prome in 1914 it is reported to have flowered over an area of about 3 square miles; this is the first record of anything approaching gregarious flowering for about fifty-five years. Since 1918 there have been signs of an approaching general flowering on the western side of the Pegu Yoma; if this materializes the life-cycle of the bamboo may be placed at about 60 years or a little more. From records available it appears to have flowered gregariously in the Upper Zamayi forests, Pegu, in 1852, but probably 1859 and 1860 were the years of most extensive general flowering in the Pegu Yoma forests, at all events in the Tharrawaddy



FIG 387. Dense growth of *Arundinaria racemosa*, Darjeeling hills



FIG. 388 Forest with undergrowth of *Arundinaria racemosa* after a fire, showing destruction of tree-growth, Darjeeling hills.

and Prome districts. Brandis¹ notes general flowering all along the west side of the Pegu Yoma in 1859, and adds : 'The jungle fires of March, April, and May subsequently swept away the tangled masses of dry stems, and after the rains of 1861 the ground everywhere was covered with millions of seedling bamboos, which soon grew up into slender plants 2 to 3 ft. high, forming dense waving green masses on the ground under the trees.'

About 750 seeds weigh 1 oz. (sample collected in 1914).

The only available record of the rate of growth is contained in the following note by Brandis :² '*Bambusa polymorpha*, which had flowered in the Pegu Yomah hills in 1859, had, when I visited those hills in 1868, grown up into a forest similar to that which I had known before flowering ; the tufts, however, were small, that is, they had not yet as many stems as formerly.'

5. *Bambusa arundinacea*, Willd. Thorny bamboo. Vern. *Kattang*, C.P. ; *Dougi*, *padhai*, *kalak*, Bombay ; *Mungil*, Tam. ; *Vedru*, Tel. : *Kyakatwa*, Burm. (Fig. 391.)

A large bamboo with bright green, fairly thick-walled culms, attaining a height of 80–100 ft. or more and a diameter of 6 or 7 in., forming dense clumps of large size. The culms produce quantities of thorny branchlets interlacing into a dense mass and rendering the culms difficult to extract from the clump. M. Velu Pillai³ records the measurement of a culm felled in November 1904 at Pattazhi in Travancore, 121½ ft. long and 20 in. in girth at its centre ; the whole clump had 112 culms, of which six measured 118 ft. in length. The culms are used for building, basket-work, &c.

This bamboo is found throughout the greater part of India, except in the driest regions, particularly along river valleys and in other moist situations. It occurs in ravines near water in the sub-Himalayan tract of Kumaun, but has probably been introduced ; it is not considered to be indigenous to the Indo-Gangetic plain or north of it, but is largely cultivated in northern India and elsewhere. It is abundant in the forests of the west coast from North Kanara southwards, particularly on flat ground near rivers and streams. In Burma it is common in parts of Pegu and Martaban, in the Moulmein neighbourhood and in the Salween and Thaungyin drainages, often along the banks of rivers. It is somewhat scarce in lower Assam, eastern Bengal, and Chittagong. Gamble says it is probably found in its largest size and finest condition in the hills of the Circars, especially about the Godavari, on the hill ranges of the eastern and southern scarps of the Mysore plateau, and in the Nilgiris.

This species, although it occasionally flowers sporadically, as in the Thaungyin forests of Tenasserim in 1916, is one of those characterized by marked gregariousness in flowering. The following years of gregarious flowering have been recorded :

Dehra Dun (planted).	1900.
Bihar and Orissa.	1913. Angul and other localities.
Central Provinces.	1869. Satpurus.
Bombay.	About 1874–84, mainly 1878. Kanara, Belgaum, Dharwar.
	About 1910. Throughout the Dangs.

¹ Indian Forester, xxv (1899), p. 4.

² *Ibid.*, p. 9.

³ *Ibid.*, xxxi (1905), p. 153.

Bombay.	About 1905-18, mainly 1912. Kanara, Belgaum Dharwar.
Coorg.	1913-15.
Madras.	1896. Parts of Walayar forest, Coimbatore. 1912-15. Commenced on plateau tracts of Wynaad and spread southwards to Kollegal and Coimbatore.

Brandis says that as far as is known it flowers at intervals of thirty-two years; the dates just quoted indicate thirty-four years as the flowering period in the southern part of Bombay, which more or less confirms Brandis's statement.

As regards rate of growth, Brandis¹ in 1876 observed thickets of young plants 15 ft. high and seven years old, the result of a general flowering in 1869 in the Pandratola reserve of the Satpuras, Central Provinces. Bourdillon² stated in 1895 that bamboos which flowered gregariously between 1879 and 1882 had not reached full size by 1895, their age being then about thirteen to sixteen years, though they were actually cut to float timber eight years after flowering. He subsequently noted,³ after actual measurements of clumps of known age in Travancore, that it requires more than twenty years for the clumps to reach full bearing, but that culms large enough to float timber are produced in twelve years.

The danger of thinning out this bamboo too heavily, resulting in the bending or breaking of the remaining culms, has already been alluded to (see p. 996 and Fig. 386).

3. THYRSOSTACHYS, Gamble.

Species 1. *T. Oliveri*, Gamble; 2. *T. siamensis*, Gamble.

1. *Thyrsostachys Oliveri*, Gamble. Vern. *Thanawa*, Burm. (Fig. 392.)

A large, handsome, caespitose, rather thin-walled bamboo, 40-80 ft. high, with straight culms, the lower parts of which are comparatively free from side branchlets. The persistent sheaths envelop the greater part of the internodes. The culms are much used for building.

This bamboo covers extensive areas on well-drained ground in the mixed deciduous forests of Upper Burma, often in association with teak, padauk, and other important trees, as in the Ruby Mines district, the Madaya forests of the Mandalay district, the Shan hills, and elsewhere. It has also been reported from Henzada. It does not occur in very moist types of forest, but is characteristic of intermediate types between these and the drier types in which *Dendrocalamus strictus* is the prevailing bamboo. It has been successfully raised from seed at Dehra Dun, where there are a number of clumps in gardens.

Gregarious flowering has been reported in 1891, in 1911-12 in the Thabeit-kyin subdivision of the Ruby Mines district, in 1914 in the Ruby Mines, Mandalay, and Meiktila districts, in 1916 in the Southern Shan States, and in 1917 in the Mandalay district. Sporadic flowering has been reported in 1902-5 in the Ruby Mines district, and in 1916 in the Henzada-Maubin forest division.

¹ Ind. Forester, xxv (1899), p. 8.

² *Ibid.*, xxi (1895), p. 229.

³ *Ibid.*, xxv (1899), p. 152.

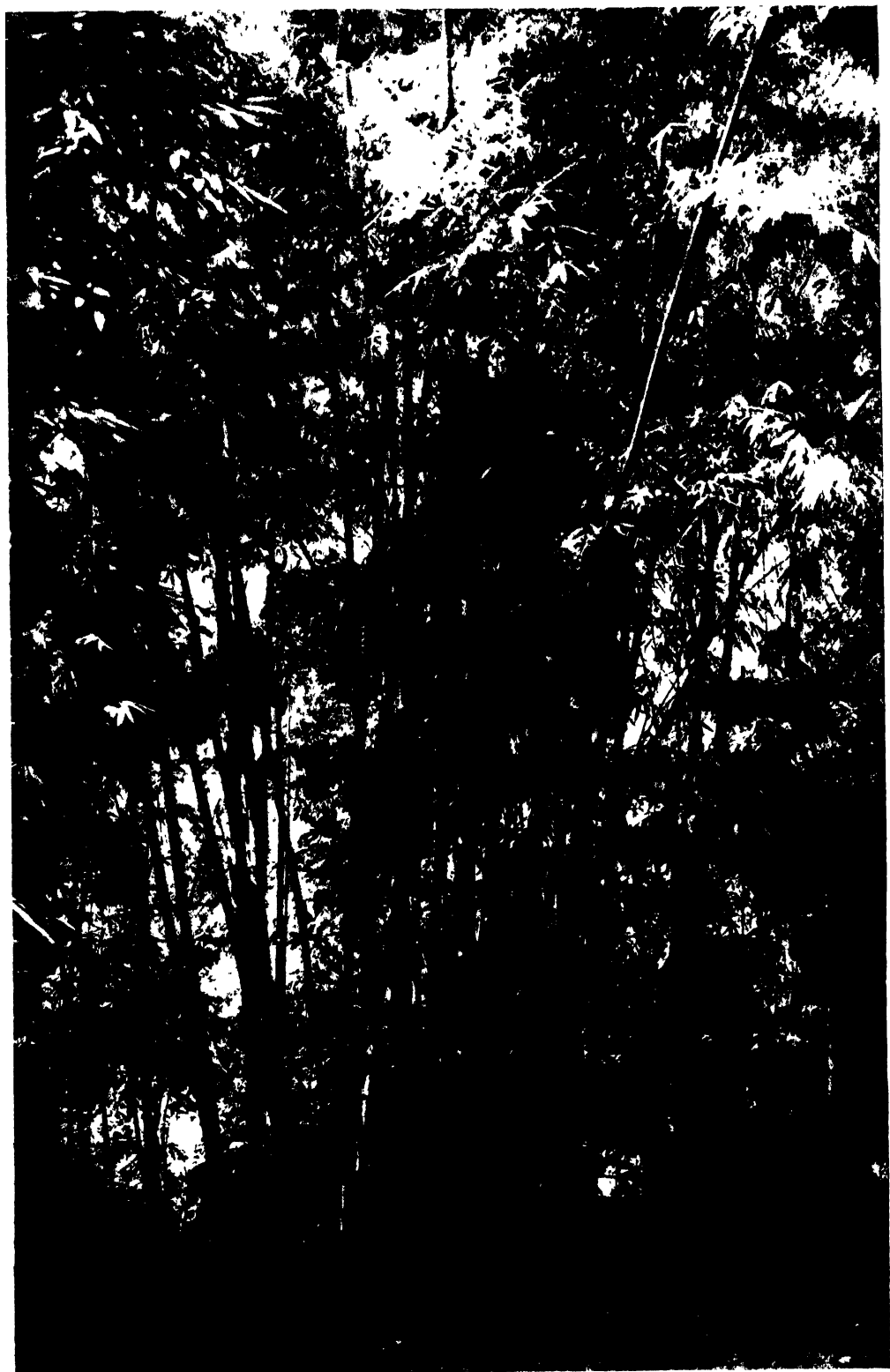


FIG 389. *Bambusa Tulda*, Chittagong hill tracts.



FIG. 390. *Bambusa polymorpha*, Burma.

2. *Thyrsostachys siamensis*, Gamble. Vern. *Tiyowa*, Burm.

A handsome caespitose deciduous bamboo with straight culms of regular growth, 25–40 ft. high, the lower parts free from branchlets, somewhat resembling but smaller and thinner than *T. Oliveri*. The culms are used in Burma for the manufacture of umbrella handles. This bamboo is cultivated in monastery compounds throughout the greater part of Burma. Brandis says it is indigenous in small side valleys of the Salween river between the Solo and Kemapyu *chaungs*, and in Siam. He also says it flowered in the Royal Botanic Gardens, Calcutta, in 1892.

4. GIGANTOCHLOA, Kurz.

Gigantochloa macrostachya, Kurz. Vern. *Tekserah*, Garo ; *Wapyugyi*, *wanet*, Burm.

An evergreen bamboo, with dark green culms often with white longitudinal stripes, attaining a height of 25–50 ft. and a diameter of 3–4 in., forming somewhat lax clumps. A native of Assam, Chittagong, and Burma. In Burma it is one of the most characteristic bamboos in the forests east of the Sittang river, where it covers extensive areas on low hills ; it is abundant round Shwegyin.

5. OXYTENANTHERA, Munro.

Species 1. *O. nigrociliata*, Munro ; 2. *O. albociliata*, Munro ; 3. *O. monostigma*, Bedd.

1. *Oxytenanthera nigrociliata*, Munro. Syn. *Bambusa auriculata*, Kurz. Vern. *Kalia*, Beng. ; *Wanwè*, Burm.

A densely tufted evergreen bamboo with culms 30–50 ft. high and up to 4 in. in diameter, dark green, sometimes with longitudinal yellow stripes. Widely distributed from the Garo hills, through Sylhet, Chittagong, and Burma, chiefly in Tenasserim, and southwards to Singapore ; also in the Andamans, in semi-deciduous forest and along streams. Often flowers sporadically.

2. *Oxytenanthera albociliata*, Munro. Vern. *Wapyu*, *wapyugale*, *wanwè*, *wagók*, Burm.

A densely tufted bamboo with thin culms which bend over, forming a nearly horizontal crown with a dense low cover. A common species throughout the greater part of Burma, chiefly in mixed deciduous forests, often on very sandy soil and sometimes on decomposing laterite. It is often markedly gregarious, and its dense low cover is inimical to the reproduction of teak and other tree species, while severe fires occur where it forms a dense growth.

This bamboo often flowers sporadically. The following gregarious flowerings have been recorded :

- 1911. Pyinmana, in part of the Yanaungmyin reserve.
- 1912. Thayetmyo, in the East Yoma reserve.
- 1913. Toungoo.
- 1914. South Toungoo, Shwegyin, Rangoon, and Yaw forest divisions.
- 1916. North Toungoo and Thaungyin forest divisions.
- 1917. Zigôn, Tharrawaddy, and West Salween forest divisions.

3. *Oxytenanthera monostigma*, Bedd.

An erect thick-walled bamboo with isolated culms up to 20 ft. or more in height and 1 in. in diameter, covered when young with a yellowish white velvety tomentum. It occurs gregariously in the Western Ghats and hills of south-west India, usually as an undergrowth in mixed deciduous forests. It is used for basket-work, but is not considered of very good quality.

6. DENDROCALAMUS, Nees.

Species 1. *D. strictus*, Nees; 2. *D. membranaceus*, Munro; 3. *D. sikkimensis*, Gamble; 4. *D. Hamiltonii*, Nees and Arn.; 5. *D. giganteus*, Munro; 6. *D. longispathus*, Kurz; 7. *D. Brandisii*, Kurz.

1. *Dendrocalamus strictus*, Nees. Syn. *Bambusa stricta*, Roxb. Male bamboo. Vern. *Báns*, Hind.; *Kiribidru*, Kan.; *Kal mungil*, Tam.; *Myinwa*, Burm.

A densely tufted deciduous bamboo with strong thick-walled or solid culms varying much in size according to locality, usually from 20 to 50 ft. high and 1-3 in. in diameter. Culms glaucous green when young, losing their glaucous appearance in the second year, and often turning yellowish when old. Branchlets from the nodes are ordinarily produced almost throughout the entire length of the culm; the lowest few nodes often produce rootlets. In dry localities on poor soil the culms, though small in size, are solid or nearly so, whereas in more fertile localities, although they reach larger dimensions they are as a rule hollow. This bamboo is extensively used for building, furniture, lance-shafts, walking-sticks, mats, basket-work, axe-handles, and numerous other purposes.

This is the best known, commonest, and most widely distributed of all Indian bamboos, occurring in deciduous forests throughout the greater part of India, except in northern and eastern Bengal and Assam; it is common in the drier types of mixed forest throughout Burma. It is found typically on hilly country, ascending to 3,500 ft. and occurring gregariously sometimes almost to the exclusion of tree growth, but usually forming an under-story to or a mixture with deciduous trees. It is not uncommon in certain types of sal forest on hilly country. It is abundant in many parts of the Siwalik tract and outer Himalaya from the Punjab eastward to Nepal, occurring most plentifully between the Ganges and Ramganga rivers. It is also common in most of the hilly parts of the Indian Peninsula, except in very moist regions. In Burma it is the typical bamboo of the drier types of upper mixed deciduous forest with or without teak; it also extends into *indaing* (dry dipterocarp) forest.

This is the hardiest of all Indian bamboos, thriving in regions which suffer periodically from excessive drought. Within its habitat it is frost-hardy. In the abnormal frost of 1905 in northern India it withstood the effects of the frost better than almost any of the tree species; only isolated clumps suffered, and in these only the younger and more tender culms were affected. In the abnormal drought of 1899-1900 in the Indian Peninsula it escaped damage, although other species of bamboo and many tree species suffered severely.

This species commonly flowers sporadically, in isolated clumps or in small groups, almost every year; it also flowers gregariously over large tracts

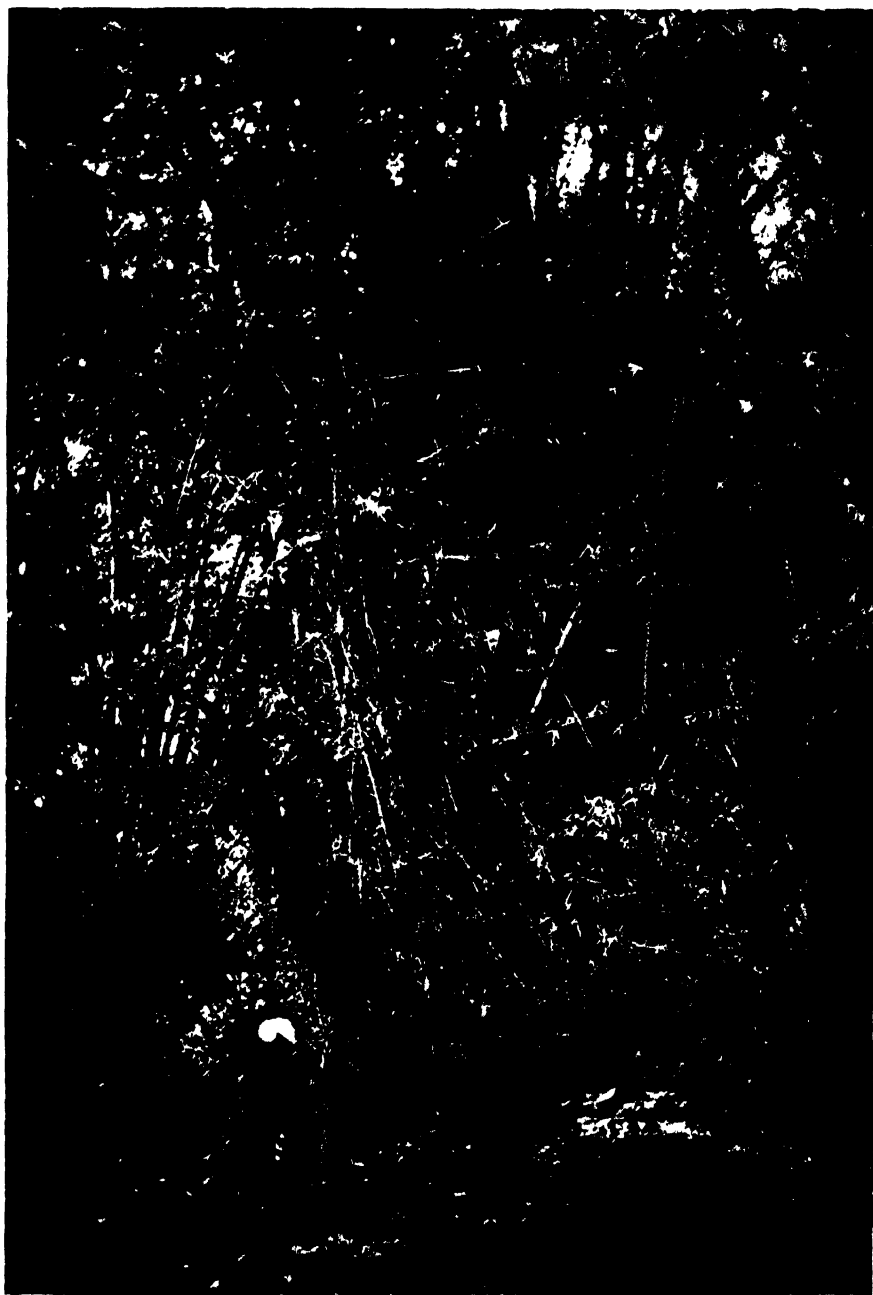


FIG. 391. *Bambusa arundinacea*, North Kanara, Bombay.

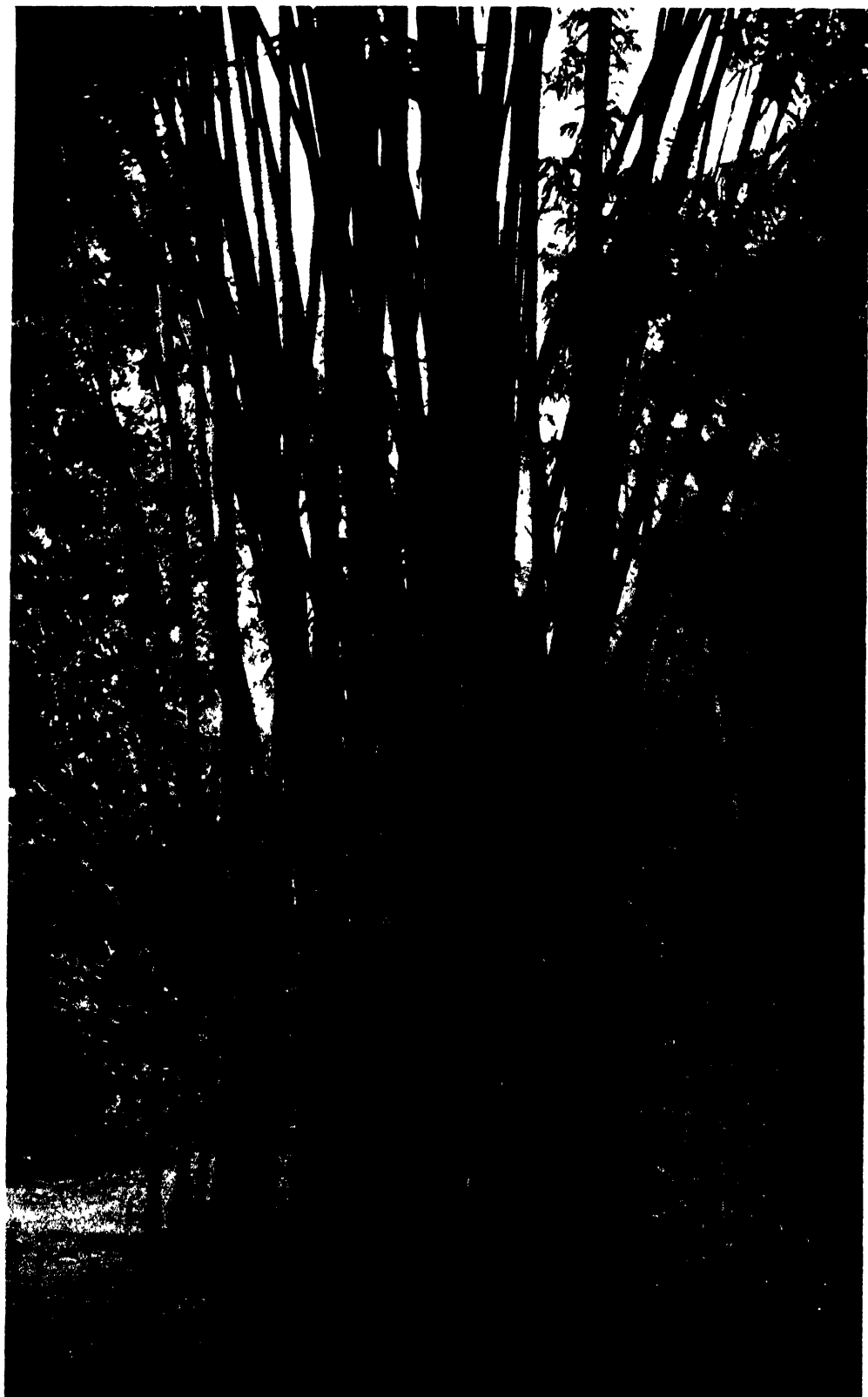


FIG. 392. *Thyrsostachys Oliveri*, Ruby Mines district, Upper Burma

at long intervals, the gregarious flowering usually taking some years to complete, and often progressing in a definite direction in successive years. Actually it is often difficult to distinguish between sporadic flowering on a plentiful scale and gregarious flowering, there being all stages between the two. In the Garhwal outer Himalayan tract the interval between the last two recorded general flowerings was between thirty-six and forty years (i. e. 1872-6 and 1908-13). Mr. A. Smythies¹ estimates the interval in the Chanda district, Central Provinces, at about thirty years. The correct periodicity, however, is difficult to determine in view of the irregular manner of flowering of this species. The flowers, in dense globular heads, appear from November to February, and the ripe seeds fall from April to June, according to locality. About 800-900 seeds weigh 1 oz. In years of abnormal drought, flowering and fruiting may occur earlier; Mr. A. E. Lowrie² notes that in the abnormal drought of 1899-1900 in the Chanda district, flowering took place early in October, and the ripe seed was shed in December. The old leaves fall as a rule from December to March and the new foliage appears from April to June. The following years of gregarious flowering and seeding have been recorded:

United Provinces.	1872-6. Garhwal outer Himalayan tract.
	1880. Oudh.
	1883-6. Saharanpur Siwaliks.
	1908-13. Garhwal outer Himalayan tract.
	1911. Bundelkhand.
Central Provinces.	1899. Seoni (Kurai and Ganginala ranges)
	1900. Balaghat (Motinala range).
	1900 and 1901. South Chanda.
	1908. Nimar (partial).
Bombay.	1901. Thana (Mokhada hills).
Madras.	1887. Kurnool.
	1890. Vizagapatam (Golgonda hills).
	1891. North Arcot.
	1894. Coimbatore (Pollachi range).
	1897. Coimbatore (part of Walayar forests).
Burma.	About 1865. Tharrawaddy.
	1888. Tharrawaddy.
	1895. Tharrawaddy (Zigôn and Minhla).
	1906. Thayetmyo.
	1908 and 1909. Henzada.
	1911-12. Ruby Mines (Thabeitkyin range).
	1911-13. Mu forest division (Inga in Wuntho range).
	1912 and 1913. Tharrawaddy (Zigôn).
	1914. Thayetmyo, Rangoon, Henzada, Upper Chin-dwin, Mu, Mandalay, and Yaw forest divisions.

The new culms are produced in the rainy season. In northern India they do not as a rule attain full length until September, but farther south they

¹ Ind. Forester, xxvii (1901), p. 126.

² *Ibid.*, xxvi (1900), p. 505.

develop earlier. In years of favourable rainfall as many as twenty may be produced from fair-sized clumps.

This species, owing to its importance and wide distribution, has subject of much more study and experiment than any other. Information on natural and artificial reproduction, the development of young plants and of clumps, the formation of congested clumps, methods of working and other details will be found in the introductory note to this tribe (pp. 985 to 998). As regards rate of development it may be repeated here that under natural conditions probably at least twelve years are required from the time of seeding until the clumps are ready for working; thus in the Dhaba range of South Chanda natural bamboos which sprang from seed in 1900 were reported in 1912 to be still too small to be readily saleable. Under specially favourable conditions working could probably be commenced from about the seventh to the tenth year; line sowings in Kaunli garden, Dehra Dun, kept regularly weeded but not irrigated, had by the sixth year formed well-developed clumps capable of yielding an average of one to two fair-sized culms per clump.

2. *Dendrocalamus membranaceus*, Munro. Vern. *Wapyu*, Burm.

A graceful bamboo, forming rather open clumps, with light green, fairly thin-walled culms, attaining a height up to 60–70 ft. and a diameter up to 4 in. The culms are useful and are employed for building. This bamboo is indigenous to Upper Burma and Martaban. It has been planted at Dehra Dun, where it grows well. Gregarious flowering has been reported in the Shweli forests, Ruby Mines district, about 1912, and in Shwegyin in 1915.

3. *Dendrocalamus sikkimensis*, Gamble. Vern. *Pugriang*, Lepcha.

A large handsome tufted thick-walled bamboo, with few culms in each clump, attaining a height of 50–70 ft. and a diameter of 5–7 in. Indigenous to Sikkim and Bhutan at 4,000–6,000 ft., and on Tura peak in the Garo hills; cultivated in India and in Europe. Sections of the culms are used in Sikkim as buckets for carrying water and milk. Gregarious flowering is reported to have occurred near Kalimpong in 1916, the seed ripening in October.

4. *Dendrocalamus Hamiltonii*, Nees and Arn. Vern. *Kaghsi bans*, Hind.; *Pecha*, Beng.; *Tama*, Nep.; *Kokwa*, Ass.; *Wabo-myetsangye*, Burm.

A large tufted bamboo, with culms sometimes erect but often overhanging and almost horizontal, with large branches. The culms sometimes attain a length of 80 ft. and a diameter of 6 or 7 in.; they are thin-walled, rather soft, and grey in colour.

Indigenous to the central and eastern sub-Himalayan region, ascending to 3,000 ft., Assam, Burma; frequently cultivated in the western sub-Himalayan region, for example at Dehra Dun and in other valleys. In Burma it is common, especially in the Bhamo, Katha, and Ruby Mines districts, where it occurs in moist places along streams and in valleys, often bending over and forming dense thickets (see Fig. 393).

This bamboo often flowers sporadically, and is easily recognized from its reddish purple flowers. The following gregarious flowerings have been recorded:

1894. Sikkim and Dehra Dun (cultivated).

1912. Northern parts of the Khasi hills.

1910, 1911, 1914. Ruby Mines district, Upper Burma.

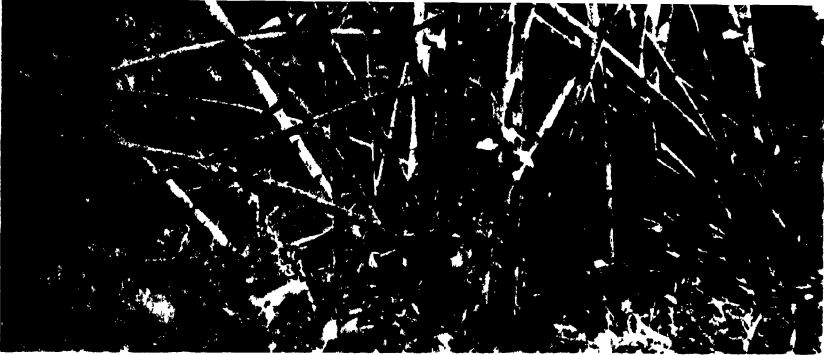


FIG. 393. *Dendrocalamus Hamiltonii*, Ruby Mines district, Upper Burma.



FIG. 394. Forest of *Cephalostachyum pergracile* (on right half of picture) and *Bambusa polymorpha* (clump on left) protected from fire for many years, showing dense growth, Tharrawaddy, Burma.



FIG. 395 *Dendrocalamus longispathus*, Chittagong hill tracts.

1916. Myittha forest division, Upper Burma.

1917. Myitkyina, Upper Burma.

5. *Dendrocalamus giganteus*, Munro. Vern. *Wabo*, Burm.

A very large bamboo with culms attaining 80–100 ft. in height and 8–10 in. in diameter, forming dense clumps. This is, with *D. Brandisii*, perhaps the largest of the bamboos. Probably indigenous to Martaban (Brandis); cultivated in many parts of Burma and in Assam, Bengal, southern India, and elsewhere. This bamboo is used for building and for masts of boats, while sections of the culms are utilized as buckets. According to Gamble it flowered in the Calcutta Botanic Gardens in 1860–1 and again in 1888. It is occasionally found in flower in Burma. An account of a plantation of this bamboo near Myanaung in the Irrawaddy delta is contained in the *Indian Forester*, vol. ii (1876–7), p. 311. This plantation, over 20 acres in extent, situated on rich sandy alluvium within half a mile of the river bank, was formed by planting, at the beginning of the rainy season, offsets consisting of the young shoots of the year with small portions of rhizome attached. The villagers estimated the age of flowering at forty years, and maintained that by planting offsets in the gaps formed from time to time by the flowering and dying of clumps the plantation could be maintained indefinitely, since young offsets so planted would complete the whole span of life before flowering, after the manner of seedling plants, the mother clump flowering and dying long before the newer clumps produced from its offsets. This, it may be noted, is contrary to what has generally been observed in the case of bamboos, namely that offsets, whatever their age, flower at the same time as the parent clumps. In the first year the offsets produced small whip-like shoots, the subsequent culms increasing in size each successive year until after seven years they attained a girth of about 10 in. and a height of about 40 ft., when they were cut for the market. The culms did not, however, attain full size until the clump had reached an age of fifteen or sixteen years. When the clump had attained maturity, all culms three years old were cut annually, each clump yielding three to four culms. The number of clumps per acre was fifteen to twenty, and the prices paid to the cultivator were Rs. 1–4–0 each for straight, mature bamboos, and 4 annas for the smallest sizes.

6. *Dendrocalamus longispathus*, Kurz. Vern. *Khang*, Beng.; *Ora*, Chittagong; *Waya*, *wanet*, *talagu-wa*, Burm. (Fig. 395.)

A large tufted bamboo, the culms attaining a height of 40–60 ft. and a diameter of 3 to 4 in., the internodes covered by long papery sheaths with irritant black hairs. A native of Sylhet, Chittagong, Arakan, and Burma. This is a well-known bamboo in the moister parts of the upper mixed forests of Burma, along the sides of ravines on moist fertile loam. It is often found flowering sporadically. Gregarious flowering has been reported in the Chittagong hill tracts in 1879, in the Tharrawaddy district of Burma in 1887 (Thonzè and Kônbin forests) and 1912 (parts of the Minhla, Mókka, and Kadinbin forests and elsewhere), and in the Toungoo district in 1913.

7. *Dendrocalamus Brandisii*, Kurz. Vern. *Wabo*, *kyellowa*, Burm.; *Thaikwabo*, Upper Burma.

A very large evergreen tufted bamboo, with culms attaining 80–120 ft. in height and 5–8 in. in diameter, along with *D. giganteus* perhaps the largest

of the bamboos. Found throughout the greater part of Burma from Bhamo southwards through the Sittang, Salween, Thaungyin, and Ataran drainages. It is frequently, but by no means exclusively, found on limestone. It flowers sporadically as well as gregariously. The only gregarious flowerings hitherto recorded have been in the Thaungyin forests in 1914 and in the Lower Chindwin in 1916. In recent experiments at Dehra Dun it was the only species tried which gave successful results in propagation by means of cuttings laid horizontally just below ground; the growth of the resulting shoots, however, was slow, a maximum height of 7 ft. having been attained in three years.

7. CEPHALOSTACHYUM, Munro.

Cephalostachyum pergracile, Munro. Vern. *Tinwa*, Burm.

A graceful deciduous tufted bamboo with thin-walled glaucous green culms, attaining under favourable conditions a height of 40 to 50 ft. or more, and a diameter of 3 in.; culm-sheaths of a characteristic orange or almost brick-red colour, covered when young with stiff black hairs. In Burma it is much used for building and mat-making. A promising source of supply of paper-pulp.

This is one of the commonest and most widely spread bamboos in the upper mixed deciduous forests of Burma, and in association with teak and other valuable timber trees is of great silvicultural importance. It occurs both in the moister types of deciduous forest with *Bambusa polymorpha* and in stunted form in the semi-dry types, verging on the driest types where *Dendrocalamus strictus* is the prevailing bamboo. It is characteristic of low, hilly country, thriving best on well-drained fresh loam, and is remarkably gregarious. It occurs, though of small size and rare, in valleys in the forest of Singhhum, Chota Nagpur; it is also said to be wild on the lower Naga hills.

Fig. 394 shows a dense growth of this bamboo, such as is characteristic of forests which have been protected from fire for some time (see also Fig. 276).

This species often flowers sporadically, and occasionally flowers gregariously over extensive areas. The following gregarious flowerings have been recorded in Burma:

About 1865. Tharrawaddy (round Kodugwe).

1875-6. Prome and Tharrawaddy; extensive flowering, embracing at least from the Bwet reserve in Prome through the Zigôn forests to the Kônbin reserve in Tharrawaddy.

About 1887-8. Tharrawaddy (Kônbin reserve).

1894-5. Tharrawaddy (Minhla) and Zigôn.

1899-1900. Pyinmana, Yônbin reserve.

1900-7. Upper Chindwin, Myittha, and Katha; commenced in Upper Chindwin and spread in a wave southwards and eastwards. Auktaw and Pile reserves, Katha, in 1905-6.

1902-3. Shwegyin (Nyaunglebin).

1904-6. Myitkyina (Indaw valley).

1906-8. Pyinmana.

1906-9. Toungoo (Gwethe and Kabaung reserves in 1906-7).

- 1907-9. Henzada.
- 1908-9. Bassein.
- 1911-12. Pegu (North and South Zamayi reserves), Shwegyin (Nyaunglebin working circle).
- 1912-13. Toungoo, Rangoon, Thayetmyo, and Minbu forest divisions.
- 1913-14. Parts of Zigôn, Tharrawaddy, Rangoon, Upper Chindwin, Myittha, Mu, Yaw, and Katha forest divisions.
- 1914-15. Parts of Zigôn, Shwegyin (Nyaunglebin), and Mansi forest divisions.
- 1915-16. Nyaunglebin, Pegu, West Salween, and Southern Shan States forest divisions.
- 1916-17. Nyaunglebin, Pegu, West Salween, and Mansi forest divisions.

Little is known about the rate of growth of this bamboo. Mr. F. A. Leete¹ says that under the most favourable conditions it takes from twelve to fifteen years to produce full-sized stems, while under unfavourable conditions the time required may be anything up to thirty years.

8. MELOCANNA, Trin.

Melocanna bambusoides, Trin. Vern. *Muli*, Beng. ; *Tarai, wati*, Ass. ; *Kayaungwa*, Arakan ; *Tabinwa, tabindaingwa, kayinwa*, Burm.

An evergreen bamboo with single culms arising at a distance of about 2 ft. apart, more or less, from a ramifying underground rhizome. The culms are straight, and attain a height of 30 to 50 ft. and a diameter of 1½ to 2½ in. Although thin-walled, they are strong and are extensively used for building, as well as for basket-work, matting, and other purposes.

This bamboo is found in the Garo, Khasi, and Lushai hills, the Chittagong and Arakan hills, crossing the crest of the Arakan Yoma into the Prome, Henzada, and Bassein districts of Lower Burma ; it is also found in the Upper Chindwin district of Upper Burma. Brandis (*Indian Trees*) regards the Tenasserim single-stemmed bamboo as a different species.

Melocanna bambusoides is a typically gregarious bamboo, and occupies extensive tracts of country in the Chittagong and Arakan hills, where the destruction of tree-growth by shifting cultivation has over considerable areas produced a veritable sea of bamboo resulting from culms which have sprung from rhizomes remaining alive in the ground after the tree-growth has been destroyed. Enumerations carried out in two separate plots of 1 acre each in Arakan gave respectively (1) 10,575 culms weighing 27,404 lb., and (2) 6,855 culms weighing 33,248 lb.

The fruit is large, fleshy, and pear-shaped, 3-5 in. long and 2-3 in. broad, the stalk being inserted at the thick end and the apex terminating in a curved beak. The thick fleshy pericarp is filled with starch, and the fruits are readily devoured by cattle, elephants, bison, rhinoceros, deer, pig, and other animals. This bamboo flowers gregariously over large stretches of country. No new culms are produced the season before flowering takes place. The flower-buds are first visible about September or October, and flowering takes place in

¹ Ind. Forester, xxxviii (1912), p. 355.

December or January. Soon after the flowering the leaves wither and fall, the culms turn yellow, and the fruit forms rapidly, ripening and falling about April to June ; large numbers of fruits fail to mature. Often as many as eight or ten fruits may be found hanging in clusters round each node down the whole length of the culm. The fruits perish rapidly, and if they are sent to a distance they require to be packed carefully in dry sand or charcoal.

Germination commences with the first heavy showers of the rainy season, roots and shoots being produced from the thick end of the fruit ; roots often begin to appear before the fruit falls. The seedlings, unlike those of most bamboos, make vigorous growth from the commencement. By the end of the first season each fruit will usually have produced about four or five shoots, of which the latest may be as much as 10 ft. high ; these shoots are crowded together in a clump. During the second season more shoots are produced, the clump expands somewhat, and the largest culms reach a height of about 20 ft. By the fifth season the culms attain almost their maximum height, but are still thin and crowded together, and it is not until later that they become spaced out with the gradual extension of the rhizomes. Young crops of bamboo are extremely dense, the rhizomes being closely interlaced. Fig. 396 shows a natural crop seven years old from seed.

This bamboo spreads to a remarkable extent by its long vigorous rhizomes. At the last general fruiting in Arakan it was also observed to spread, owing to the rolling of the heavy fruits down the hill-sides, to places where it did not exist before, and was found springing up on savannahs and in beds of streams. It does not thrive well under shade, but springs up readily in gaps.

As an instance of the great vigour and vitality of the rhizomes, it may be mentioned that Mr. W. D. Turner of Hurbanswala, Dehra Dun, obtained seeds from Assam in 1912, of which six germinated successfully and produced strong plants, which grew and spread rapidly on moist fertile ground. In 1917 he was able to dig up no fewer than 400 offsets for transplanting elsewhere, after which a fairly large grove of bamboos still remained in the parent crop ; the appearance of this grove early in 1919, after seven rainy seasons' growth from seed, is shown in Fig. 397. Small portions of the rhizomes left lying on the ground when the offsets were dug up immediately took root and sent up strong shoots from dormant buds. The propagation of this bamboo from sections of rhizome, therefore, is an easy matter. The vitality of the rhizomes is well demonstrated in the natural home of this bamboo by the difficulty experienced in eradicating it on ground cleared for cultivation, for areas cleared one year become thickly covered with bamboos the next year. On this account the *taungya*-cutters in the Arakan hills are said to prefer flowered areas for making their clearings ; the large fruits are easy to collect off the ground, the reproduction of the bamboo being thus prevented, and the subsequent weeding of the cultivated patches being rendered much easier.

Experiments were carried out in Arakan at the last general flowering in order to ascertain the best means of eradicating this bamboo in the interests of tree-growth. It was found that if the bamboos were cut in the cold weather when about to flower, they flowered from dwarf shoots next year. By cutting the culms down in April when the fruits were almost ripe, however, the rhizomes were killed and the great majority of the fruits were destroyed.

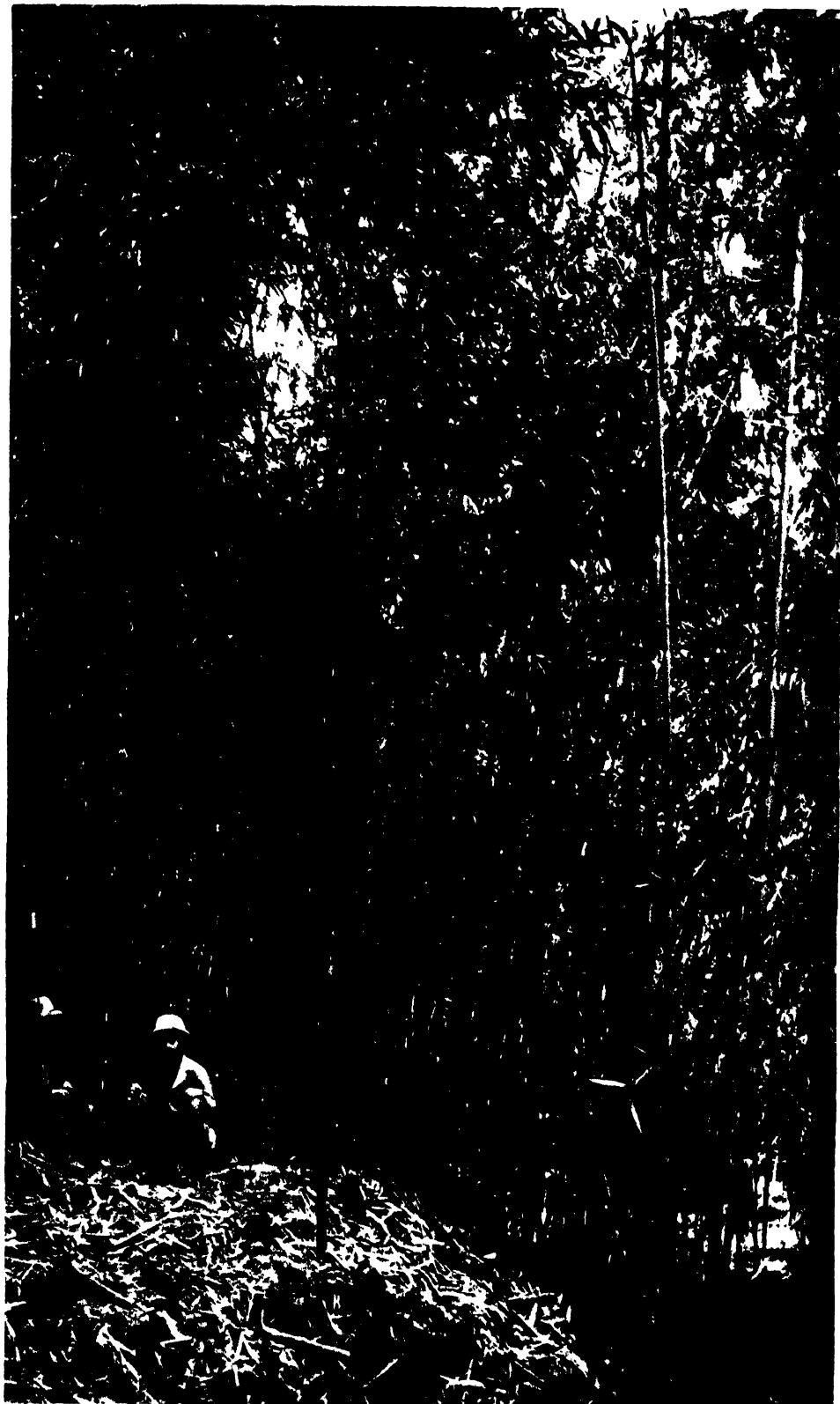


FIG. 396. *Melocanna bambusoides*, natural crop 7 years old, Chittagong hill tracts



FIG. 397. *Melocanna bambusoides*, 7 years old, artificially raised from seed, Dehra Dun.

The following instances of general flowering have been recorded :

- 1863-6. Chittagong and Arakan, extensive flowering, also in Botanic Gardens, Calcutta.
- 1889. Garo and Khasi hills.
- 1892. Assam.
- 1900, 1902. Garo and Khasi hills.
- 1901-2 and 1904-5. Chittagong and Arakan, apparently over restricted areas.
- 1908-12. Chittagong : extensive flowering.
- 1910-13. Arakan : extensive flowering, spreading in 1912-13 to the east side of the Yoma into the Prome, Henzada, and Bassein districts.
- 1910-11. Assam (Sylhet).
- 1911-12. Assam (Garo hills, Cachar, Sylhet, Lushai hills).
- 1915-16. Arakan.

ORDER LXIII. CONIFERAE

A very important order, represented mainly in the Himalaya, and to some extent in the hills of Assam and Burma ; only one species (*Podocarpus latifolia*, Wall.) is indigenous to the Indian Peninsula. Several of the Himalayan conifers are of great importance from a silvicultural and economic point of view, and many of them grow gregariously, unlike most of the broad-leaved trees of India. Apart from the introduced species mentioned below, several exotic conifers are cultivated for ornament in India, among which may be mentioned *Thuya orientalis*, Linn., *Cunninghamia sinensis*, R. Br., *Araucaria excelsa*, R. Br., *A. Cunninghamii*, Ait., and *Ginkgo biloba*, Linn. ; none of these, however, is of special forest importance. Two rather rare species of *Cephalotaxus* are indigenous : *C. Mannii*, Hook. f., in the Khasi, Jaintia, and Naga hills, and *C. Griffithii*, Hook. f., in the Mishmi hills, Manipur, and the hills of the Ruby Mines district, Upper Burma.

Genera 1. PINUS, Linn. ; 2. CEDRUS, Link ; 3. ABIES, Juss. ; 4. PICEA, Link ; 5. TSUGA, Carr. ; 6. LARIX, Miller ; 7. CUPRESSUS, Linn. ; 8. JUNIPERUS, Linn. ; 9. CRYPTOMERIA, Don ; 10. CALLITRIS, Vent. ; 11. PODOCARPUS, L'Hérit. ; 12. TAXUS, Tourn.

1. PINUS, Linn.

Evergreen trees, generally with whorled branches. Five species in the Indian region, of which three are Himalayan, *P. excelsa*, Wall., *P. longifolia*, Roxb., and *P. Gerardiana*, Wall. ; one, *P. Khasya*, Royle, occurs in Assam and Burma, and one, *P. Merkusii*, Jungh., is found in Burma. The bark of most pines is rough, thick, and fissured ; *P. Gerardiana* is a representative of a small group with thin, smooth bark exfoliating in large thin scales.

In most pines a single whorl of branches is produced each year, the internode representing one year's growth. Young and vigorous trees, however, may often produce two whorls in one year by the development of a summer shoot in continuation of the spring shoot ; the summer internode is usually much shorter than the spring one. This often occurs in *P. excelsa* and

P. Khasya. Scattered side branches, not in regular whorls, are commonly produced by *P. Gerardiana*.

The leaves are of three kinds : (1) primordial leaves, found on seedlings or on shoots produced by saplings after injury ; these are solitary, linear lanceolate, spreading ; (2) scale leaves, containing in their axils the fascicles of adult leaves, usually quickly deciduous, with persistent bases ; (3) adult leaves, needle-like, in fascicles of 2, 3, or 5 in Indian species, situated on short arrested branchlets which fall with the needles ; the base of each fascicle of needles is enclosed in a sheath formed by the scales of the buds of the arrested branchlets, and the sheath is either quickly deciduous (*P. excelsa*, *P. Gerardiana*) or persistent (*P. longifolia*, *P. Khasya*, *P. Merkusii*).

Of the Indian pines *P. Merkusii* is 2-needled, *P. longifolia*, *P. Gerardiana*, and *P. Khasya* are 3-needled, and *P. excelsa* is 5-needled. The adult needles persist from one year and a few months to several years.

The flowers are monoecious. The male flowers, catkin-like, in the axils of membranous bracts, are spirally arranged in dense clusters at the base of the current year's young shoot ; the flowers fall soon after maturing. The female flowers, or young cones, solitary or two or more in pairs or whorls, are situated at the apex of the current year's young shoot ; they consist of a central axis round which are spirally arranged two sets of scales, namely a series of larger ovuliferous scales each bearing two pendulous ovules and a series of smaller scales which disappear before the cone ripens. Pollination takes place in the first year, shortly after the first appearance of the flower ; the scales open to receive the pollen and close immediately afterwards. Fertilization is not completed, that is, the pollen-tube does not reach the embryo-sac, until the early part of the second year ; thus the cone remains comparatively small during the first season, and commences to increase conspicuously in size only during the second season.

The fruit is a woody cone composed of spirally arranged scales, with two winged seeds on each scale. The end of each scale, which is exposed in the unopened cone, is called the apophysis, in the centre of which is a knob or scar known as the umbo, which represents the apex of the scale in the first year's growth of the young cone. In most pines, and in all Indian species, the cones open on the tree without assistance, the seeds escaping and falling to the ground, or, in large-winged species, being carried some distance by wind ; in *P. Gerardiana* the wing is short and deciduous. The open cones remain for a time on the tree, in some cases for several years. In some non-Indian species the cones open only by the aid of fire or of squirrels and other animals.

Germination is epigeous, and the testa is carried up like a cap over the extremities of the cotyledons, which in Indian species vary in number from six to thirteen.

The Indian pines are all light-demanders, *P. longifolia* probably being the most marked in this respect, though on hot, dry aspects even this species benefits in youth by slight shade, particularly of broad-leaved species. Requirements for natural reproduction are more or less similar in all the Indian pines, which reproduce freely with abundance of light on recently exposed ground, such as abandoned cultivation and areas recently overrun by fire, particularly where the soil is free and loose. Young pine crops suffer severely from fire,

and wherever there is any inflammable soil-covering, that is, in the majority of cases, protection from fire is essential for the satisfactory establishment of reproduction. On the other hand, fire is useful in preparing a germinating bed by removing the thick layer of needles or too dense a soil-covering of grass or bushes.

Certain exotic pines are occasionally planted in India on a small scale. In the Nilgiris small plantations have been formed of *P. Pinaster*, Solander (2-needed), the maritime or cluster pine of Europe, and *P. radiata*, Don (*P. insignis*, Douglas, 3-needed), the Monterey pine of California. Neither species thrives well; the latter grows well in the earlier stages, but subsequently falls off. *P. Pinaster* is occasionally planted in the Himalaya, and does moderately well in some localities at about 7,000 ft. *P. sylvestris*, Linn. (2-needed), the Scotch pine of Europe, has been planted in one or two places in Jaunsar, at about 8,000–9,000 ft., but does not thrive.

Species 1. *P. excelsa*, Wall.; 2. *P. longifolia*, Roxb.; 3. *P. Khasya*, Royle; 4. *P. Gerardiana*, Wall.; 5. *P. Merkusii*, Jungh.

1. *Pinus excelsa*, Wall. Blue pine. Vern. *Kail*, Hind.; *Beyar*, *biar*, Kashm., Haz.

A large evergreen tree with bluish feathery foliage. Branches whorled, spreading, usually ascending in young trees and horizontal or drooping in old trees, with upturned ends; branchlets glabrous, glaucous. Two whorls are often produced in one season, the second or summer whorl being only a few inches above the first or spring whorl, below which is the long spring internode of the current year. Adult needles in fascicles of 5, 5–8 in. long, shorter in stunted or sickly trees, bluish green, slender; basal sheath 0.5–0.9 in. long, quickly deciduous. Fascicles of needles arranged in spirals of 5 × 3. Abnormal fascicles containing 4, 6, or even 7 needles may be found occasionally. Bark on young stems and branches greenish grey, smooth and thin, soon becoming scaly, grey, or greyish brown, divided into small oblong plates by shallow fissures. Measurements of bark thickness are given on p. 1033. Wood moderately hard, with a pink heartwood, of good quality, less durable than deodar but easily worked, and much used for building, especially interior work, furniture, and general carpentry. The resin yielded by this pine is superior to that of *P. longifolia*, but systematic tapping operations on a large scale have not yet been organized.

When growing vigorously, and before reaching old age, this is one of the most beautiful pines in the world, its long bluish drooping needles and regular growth giving it a particularly graceful appearance; as it becomes old, however, it loses its graceful form and tends to become ragged. Under favourable conditions the tree reaches large dimensions. The following measurements have been recorded by Rai Bahadur Keshavanand in the Kishanganga valley, Kashmir:¹ (1) height 165 ft., girth 9 ft.; (2) height 147 ft., girth 6 ft. 11 in.; (3) height 146 ft., girth 6 ft. 11 in.; (4) height 110 ft., girth 16 ft. In the case of 55 mature trees (i. e. 6 ft. and over in girth) he found the average height to be 118 ft., and the average girth 8 ft. 7 in. These measurements are exceptional. Under favourable conditions a height of 120 ft., with a girth of 8–10 ft., is not uncommon, while larger dimensions are attained. A tree 125 ft. high and

¹ Working Plan for the Karnah-Drawa Forests, Kishanganga Valley, Kashmir.

10 ft. 10 in. in girth measured by me in 1914 in Kulu probably falls short of the maximum attainable in that locality. In 1918 I measured a tree 12 ft. 4 in. in girth and 110 ft. high in the Kagan valley, Hazara. Fig. 398 shows a tree 9 ft. in girth and 110 ft. in height. In many places, however, a height of only 80-100 ft. is reached, while on poor shallow soil and exposed situations the trees are often stunted, attaining a maximum height of only about 30-50 ft.

DISTRIBUTION AND HABITAT. *Distribution and types of forest.* The blue pine is found throughout the temperate regions of the Himalaya, chiefly at 6,000-10,000 ft., but sometimes ascending to 12,000 and descending to 4,000 ft., extending westward to Afghanistan and Kafiristan and eastward to Bhutan, though absent from Sikkim and a considerable portion of Kumaun. Its altitudinal range is greater than that of any other Himalayan conifer. At the lower elevations it descends into the region of *Pinus longifolia*, with which it is frequently associated at the upper limits of the latter. At the higher elevations it ascends into the region of birch and juniper, but here it is stunted and often so broken and bent down by snow as to assume a shrubby prostrate form. In the western Himalaya the blue pine is most abundant between 6,000 and 8,500 ft. ; here the tree is typically gregarious, often forming extensive pure crops owing to its capacity for springing up in dense even-aged masses on open hill-sides and on abandoned cultivation. In such cases the effect of aspect is very marked, for the pine as a rule affects the warmer slopes and spurs, while the cold aspects and depressions are occupied by the silver fir, spruce, and broad-leaved species. At the lower elevations, however, where *Pinus longifolia* is the associate species, the latter occupies the hotter slopes and spurs, while the blue pine clings to the colder aspects and the moister depressions. In spite of its tendency to form pure crops the blue pine very frequently occurs mixed with other species, of which the commonest are, among conifers, deodar, spruce, and silver fir, and among broad-leaved species, oaks (*Quercus incana*, *Q. dilatata*, and at the higher elevations, *Q. semecarpifolia*), *Rhododendron arboreum*, *Pieris ovalifolia*, *Populus ciliata*, *Cornus macrophylla*, *Prunus Padus*, *Cedrela serrata*, *Aesculus indica*, *Acer caesium*, *A. pictum*, *Ulmus Wallichiana*, and others.

Among conifers the most important companion of the blue pine is the deodar. The conditions of locality which favour the two are in many respects similar, and mixed crops of the two trees are frequently met with. The mixture of blue pine and oak (*Q. dilatata* or *Q. incana*) is also common, the pine usually flourishing well with the oak. Where, as is often the case, the oak is subjected to systematic lopping, instances may be seen of oak forest being converted gradually into forest of pure blue pine through the admission of light which favours the spread of the latter. The mixture of blue pine and spruce (*Picea Morinda*), which is common, is one in which the pine usually reaches large dimensions.

Undergrowth in the blue pine forests is sometimes absent owing to the density of the crop. In fairly dense crops, however, maidenhair fern and wild strawberry often cover the ground, and are indicators of good soil conditions. Where light is sufficient there may be a plentiful growth of grass, while shrubs and herbaceous plants also make their appearance. In open places where the



FIG. 398. *Pinus excelsa* tree, girth 9 ft., height 110 ft., Bashahr.



Fig. 399. Mixed forest of *Pinus excelsa*, *Cedrus deodara*, *Picea Morinda*, and *Abies Pindhor*, upper Siran valley, Hazara.



FIG. 400 Crop of *Pinus excelsa* approaching maturity, Hazara,
North-West Frontier Province.

pine springs up so freely, among the best indications of suitable soil conditions are *Indigofera* and *Desmodium*. But perhaps the best indicator of all is the bracken fern, *Pteris aquilina*, the presence of which is a sure sign that conditions are favourable for the pine, so much so that the bracken is one of the most characteristic plants in localities where the blue pine grows in greatest profusion.

As regards local occurrence, in the western Himalaya the blue pine extends in an almost unbroken succession of pure or mixed crops at suitable elevations from Garhwal through Jaunsar, the Simla Hill States, Bashahr, Kulu, Chamba, Kashmir, the Murree hills, Hazara, and into the tribal territory beyond. In Jaunsar, Tehri Garhwal, the Simla hills, and Bashahr pure forests occur chiefly between 6,000 and 8,500 ft., but between these elevations mixed forests of blue pine and deodar, often with oak, are also frequent. In Kulu pure crops of blue pine are to be found occasionally as low as 4,500 ft. on northerly aspects. Mixed crops of deodar and pine, often with spruce, are frequent between 5,500 and 7,500 ft., sometimes higher.

In the Murree hills of the Rawalpindi district the pine appears first at about 4,000 ft. in moist ravines on cool northerly aspects, while on southerly aspects it commences at about 5,500 ft. From these elevations up to about 6,000–6,500 ft., according to aspect, it is mixed with *Pinus longifolia* and oak (*Quercus incana*), and above this it occurs either pure or mixed with oak, poplar, horse-chestnut, and other broad-leaved species. In Hazara the blue pine is well represented between 6,000 and 10,000 ft. It occurs either in the form of pure crops, usually on spurs and warm aspects, or mixed with other species. Pure crops of large extent and excellent quality occur, particularly in the Thandiani range. Fig. 400 shows a mature crop in this locality. In the Dungagali range the extent of the pine crops is smaller. In the upper Siran valley and the Kagan valley the extent of pure pine crops is considerable. The mixed crops vary in composition. In the Dungagali and Thandiani ranges the chief conifer associated with the blue pine is the silver fir (*Abies Pindrow*), which, however, seeks cool aspects, moist depressions, and upper slopes, while the pine seeks warm aspects, dry spurs, and lower slopes, though the two are often intermixed. Broad-leaved species, such as oak (chiefly *Q. dilatata*), poplar, maple, horse-chestnut, and bird-cherry, are also frequently found in mixture with these two conifers, while there is often a plentiful underwood of yew. In the upper Siran and Kagan valleys there are considerable areas of mixed forest in which the pine is associated with spruce, silver fir, and deodar, as well as broad-leaved species, including much walnut; here again the pine is more typical of the warmer aspects, and the silver fir of the colder aspects, moist depressions, and upper slopes. Fig. 399 shows a mixed coniferous forest in the upper Siran valley.

In the tribal territory adjoining Hazara the blue pine is plentiful in Agror. In Chitral it occurs in cool situations in the upper parts of the valleys, along with deodar. Here the rainfall is scanty, but there is a heavy snowfall in winter. According to Mr. Stebbing,¹ the blue pine occurs sparingly, associated with *Pinus Gerardiana*, on the Takht-i-Suliman range and in the Sherghali forest to the south of the Takht on the western slopes of the Suliman range.

¹ Note on the Chilgoza Forests of Zhob and the Takht-i-Suliman, For. Bull. No. 3, 1906.

It is commonest in ravines and on easterly aspects. This tract is a particularly dry one, and the occurrence of the pine is accounted for by the presence of moisture held up in depressions or pockets in the limestone formation. In places it grows on the sides of sheer limestone cliffs. In the Torgai nala on the Takht-i-Suliman the trees attain large dimensions.

In Bhutan, Mr. Jacob¹ notes that the blue pine grows chiefly between 8,500 and 10,500 ft., descending to 7,000, and ascending to nearly 11,000 ft. At the higher elevations it is usually mixed with spruce. It attains a large size and reproduces well.

Kashmir contains large areas of blue pine in the drainage of the Jhelum river and its tributaries, chiefly between 6,000 and 10,000 ft., but sometimes descending below 6,000 ft. It occurs either pure or mixed with deodar, spruce, silver fir, or broad-leaved species.

Geology and soil. The blue pine is found on a variety of geological formations. It thrives on moderately dry soils, but provided the drainage is good it grows best on moist, fresh, deep soil; it avoids very wet and badly drained ground. It sometimes springs up in great abundance on boulder and gravel deposits in the beds of streams, showing its partiality for a porous soil with a fair amount of subsoil moisture. Some of the best blue pine forests are found on mica schist, which decomposes into a moist fresh soil, often of considerable depth. On shale the growth varies much according to the hardness of the rock and the depth of the soil; where the soil is shallow the trees tend to be stunted. Limestone is favourable where there is a sufficient depth of soil, otherwise the soil becomes too dry for the pine to thrive. The effect of geological formation in determining the local distribution of the blue pine and chir pine towards the lower limit of the former is well illustrated below Bandal in the Tirthan valley, Kulu. Normally the blue pine occurs above the chir, but in this locality there is a belt of pure blue pine on moist mica schist, while above it is a belt of pure chir on quartzite, on which owing to the dryness of the soil the blue pine is unable to compete with the chir; higher up the blue pine again makes its appearance on mica schist.

Climate. Most of the important blue pine forests are situated in regions where the rainfall varies from 40 to 75 in. In Bhutan, however, the rainfall is probably well over 100 in., while in the Suliman range the pine occurs where possibly little more than 10 in. of rain fall in the year, but here, as already mentioned, its existence is believed to be due to the occurrence of pockets of moisture in depressions in the limestone formation. The blue pine does not extend so far as the deodar into the inner dry valleys of the western Himalaya. Temperature statistics are insufficient to give any accurate idea of the temperature conditions within the region of the blue pine. The absolute maximum and minimum shade temperatures respectively are 94° and 19° F. at Simla, 91° and 19° F. at Chakrata, and 102° and 17° F. at Murree. In the region of the blue pine, therefore, the absolute maximum may be placed at slightly over 100°, while the absolute minimum towards its upper limits must be near, if not below, zero Fahr. Throughout its habitat snow falls during the winter.

¹ Report on the Forests of Bhutan bordering on the Boundary of Eastern Bengal and Assam, 1912.

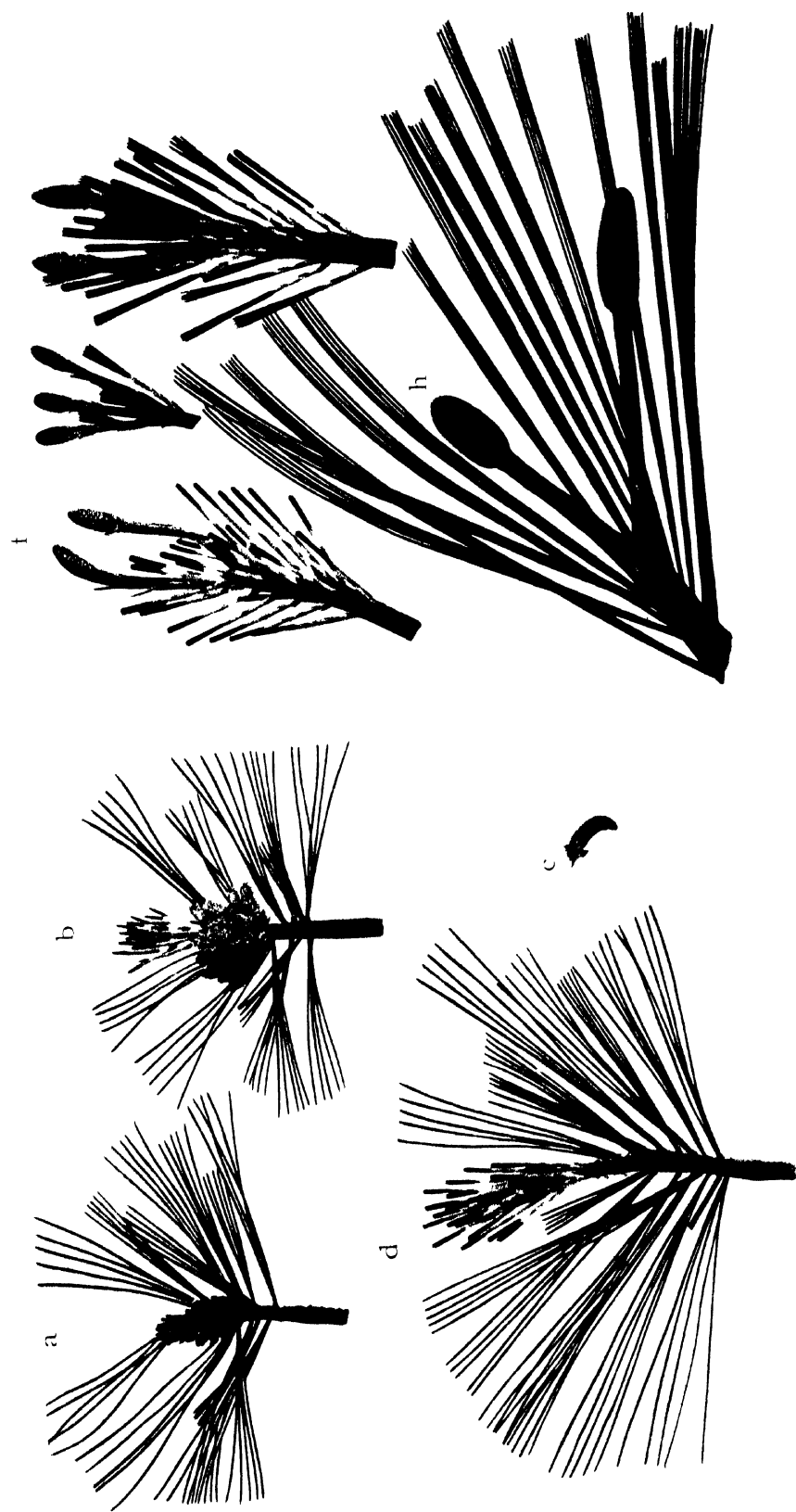


FIG. 401. *Pinus cyclops*—MALE AND FEMALE FLOWERS AND DEVELOPMENT OF YOUNG CONE $\times \frac{1}{2}$

a—Immature male flowers, April
 b—Male flowers at time of shedding pollen, May
 c—Single male catkin after falling, with involucre of scales
 d—Branchlet from which male flowers have all fallen, after shedding pollen
 e—Female flowers at time of pollination, May
 f—Female flowers after pollination, scales closed
 g—Female flowers a few weeks later
 h—Young cones towards end of first season, October
 i—Young cones towards end of first season, October
 (Note: In each case last year's needles are shown partly cut off; needles in h should be somewhat more lax than shown.)

LEAF-SHEDDING, FLOWERING, AND FRUITING. The new shoots appear in March or early April, according to locality; by August to September the needles have attained full size (5–8 in. in length, or shorter under unfavourable conditions), and their basal sheaths have fallen. The needles persist either for one year and two or three months or, in part at least, for a second year. The normal season for the shedding of needles is the summer, chiefly during May, June, and July. In June–July the trees often have a somewhat bare appearance, many of the old needles having fallen, while the new ones have not yet expanded fully and are in tufts resembling tar-brushes. The needles are usually shed earlier in the case of less vigorous trees, at high elevations and on exposed ridges, than in the case of vigorous poles in favourable situations. Sometimes partial shedding of needles takes place at seasons other than the usual one, particularly from October to December.

Male flowers. The male flowers (catkins) ripen and shed their pollen from the end of April to the beginning of June, this taking place earliest at low elevations and in hot dry seasons. The male catkins are arranged in rather indistinct spirals in a cluster 0.5–2 in. long at the base of the current year's young shoot (Fig. 401, *a* and *b*). The catkins themselves immediately before ripening are 0.3–0.4 in. long, usually green but sometimes dark reddish purple; they lengthen to 0.4–0.8 in. after shedding their pollen, and when ripe are yellow to light brown, and often pink towards the apex. They fall soon after ripening. The base of the catkin is enveloped by an involucre of 8–12 imbricate scales, which adheres to the catkin when it falls (Fig. 401, *c*). The position of the catkins, after the fall, is marked on the shoot by a portion devoid of needles, and bearing only the small scales in the axils of which the catkins were situated (Fig. 401, *d*).

Female flowers and development of cones. The young female flowers become visible in April, and are pollinated from the end of April to the beginning of June, according to elevation, locality, and season. The flowers (young cones) are erect and terminal on scale-covered peduncles 1–1.5 in. long, solitary or usually two or three together, sometimes more, at the ends of the new shoots, forming a whorl round the terminal bud. At the time of pollination the flowers are 0.4–0.5 in. long by 0.15 in. in diameter, dark reddish purple, with scales open (Fig. 401, *e*); the scales are arranged in spirals of 5×3 . After pollination the scales close (Fig. 401, *f*), the young cones increase somewhat in size, becoming 1–2 in. long by 0.4–0.5 in. in diameter by August, with a glaucous green or purplish colour, and the peduncles elongate to 1.3–2.5 in. (Fig. 401, *g* and *h*); they remain in this condition for the remainder of the first season.

Fertilization is not completed until the beginning of the year after pollination. An examination by Mr. G. H. Alington of young cones at the end of June, two months after pollination, showed that the pollen grains had entered the micropyle of the ovules and lodged on the nucellus, but so far had not produced pollen tubes, while the embryo sacs were not yet fully developed.

The young cones which first appeared in the spring of the previous year begin to grow towards the end of March or during April of the second year, and growth, once started, is rapid. The growth of the new season's terminal

shoot throws the young cones out of the terminal into a horizontal position. and as they increase in size and weight they become pendulous instead of erect. The immature cone of the second season is bluish green, each scale being tipped with a small brown umbo, the remains of the first season's scales (Fig. 402, *a* and *b*) ; full length is attained from the latter half of June to the early part of August, according to elevation and locality, and the cones gradually turn from green to light brown from the end of August to the early part of October. They ripen, the scales opening and the seed being shed, from the end of September to the early part of November. The ripe cones (Fig. 402, *c* and *d*), generally two or three together, pendulous on peduncles 1.3–2.5 in. long, are cylindrical, 6–13 in. long, light brown, with scales arranged in spirals of 5×3 , 1.5–2.5 in. long by 0.8–1.3 in. broad, apophysis convex, more or less rhomboidal, with a small dark brown umbo.

Thus the time taken from the first appearance of the female flower to the ripening of the cone is approximately eighteen months.

The old open cones may remain some time on the tree ; I have found them, by counting internodes, occasionally persisting for five years or even more, though this is exceptional.

Succession of cones and flowers. The immature cones, as already explained, are terminal during the first season, becoming lateral after the succeeding season's growth commences. These lateral cones, whether immature or mature, are thus found at the nodes of the branches and branchlets, and immediately below the whorls of branchlets ; on young trees cones are occasionally found on the main stem. From April to about October there are two succeeding stages of immature cones, one terminal and small and the other lateral and larger, followed by one or more stages of mature open cones, while from about October to April there is one stage of immature small terminal cones followed by one or more stages of mature open lateral cones. These successive stages, where all are present, differ in age by one year, and by counting the whorls the age of any stage of cones can be determined exactly. Each successive stage, however, is not necessarily present on one tree or branch ; indeed it would be exceptional to find a continuous succession for a series of years. Thus Figs. 404 and 405 each show three stages with a fourth wanting. Male flowers may sometimes be found succeeding females of the previous season.

Seed and seeding. The winged seeds lie in pairs at the base of each cone scale. Seed without wing 0.25–0.4 in. by 0.15–0.2 in., dark brown, ovoid, compressed, acute at both ends, with a hard shell ; seed with wing 1–1.5 in. long, wing 0.3–0.4 in. wide, oblique, light brown streaked with darker brown lines (Fig. 402, *e*). On an average about 7,500 seeds weigh 1 lb., though the actual weight of different samples varies considerably.

The blue pine seeds at a comparatively early age, trees ten to twelve years old being occasionally found with well-formed cones on them, while as a general rule cones begin to be formed regularly at an age of fifteen to twenty years. I have carried out various fertility tests with seed collected in Jaunsar from trees of different ages, with the following results :



FIG. 402. *Pinus excelsa*—DEVELOPMENT OF CONE DURING SECOND YEAR $\times \frac{1}{4}$

Pinus excelsa : fertility tests of seed collected in Jaunsar.

No. of test.	Locality.	Dimensions of tree.			Length of cone. in.	Percentage of fertility.
		Age of tree. years.	Girth at breast-height. ft. in.	Height. ft.		
1	Bodyar, 8,000 ft.	10				30
2	"	18				84
3	"	20				55
4	"	26				55
5	Kathiyan, 7,000 ft.	28	1 3	38	5	75
6	Bodyar, 8,000 ft.	29				83
7	Kathiyan, 7,000 ft.	34	2 0	54	5.5	90
8	Bodyar, 8,000 ft.	40				70
9	Kathiyan, 7,000 ft.	41	3 0	65	9.4	85
10	"	45	4 0	77	10.1	90
11	"	48	5 0	87	10.5	50
12	Deoban, 9,000 ft.	50				40
13	Kathiyan, 7,000 ft.	100	7 0	113	12.5	95

These figures show that a fair proportion of fertile seed is produced at a comparatively early age. Observations show, however, that as long as the trees remain vigorous the number of cones produced increases with the size of the crown, that is, with the size of the tree, and consequently seed-bearers should be selected where possible from among the larger vigorous trees with well-developed crowns. This, however, though important, is not so necessary as in the case of *Pinus longifolia*, which, unlike the blue pine, reaches a definite stage when the conical crown gives place to the rounded crown which marks the good seed-bearer.

I noticed in 1911 a remarkable example of early seeding round a small blue pine plantation below Chaubattia in the Kumaun hills. The plantation was then thirty-four years old, and round it were natural seedlings up to seventeen years old, the oldest of which were in their turn producing cones. The trees in the plantation must have begun to produce fertile seed at an age of not more than seventeen years, since the blue pine is not indigenous to the locality, and there were no other trees of that species in the neighbourhood.

Tests at Dehra Dun have shown that the seed retains its fertility, to some extent at least, for eighteen months ; no older seed was tested.

Good seed-years are more frequent in the case of the blue pine than in that of any other important Himalayan conifer. In the Murree hills, in eight years out of nine consecutive years, 1905 to 1913, good seeding was recorded five times and bad seeding three times. In Jaunsar, in sixteen years out of twenty-one consecutive years, 1894 to 1914, good seeding was recorded ten times and bad seeding six times. A certain amount of seed is produced almost every year, complete failure to seed being rare.

Probable good seed-years can be foretold about eighteen months in advance of the seeding, by examining, preferably with the aid of field-glasses, the production of female flowers at the apices of the new shoots in the end of April or during May. The crop of cones may, however, be largely or completely destroyed in the immature state by animals and birds. Of the former, monkeys and flying squirrels are the chief offenders, more especially the squirrels, which destroy large quantities of green cones of the second year, from about

May onwards. The damage may be detected from the fact that the ground is strewn with the green cone scales and the cone axes from which the scales have been bitten off sharp at the base. Both the common western Himalayan species are concerned, namely, *Pteromys inornatus*, Geoffroy, the large red flying squirrel, and *Sciuropterus fimbriatus*, Gray, the smaller flying squirrel. These animals are nocturnal. In May 1916 I watched the latter with the aid of an electric lamp, for four successive nights, devouring the cones on a small blue pine tree at Simla, and in that time the tree was stripped of all its cones, about 120 in number; the cones were then about 4 in. long, green and tender, and the young seed was apparently the part sought for, since the scales and axes of the cones were discarded. Although on this occasion I saw only one animal, there may have been more, but at all events the destruction of even thirty cones per night by a colony of squirrels for say five months, from May to September, would mean a loss in one season of nearly 4,600 cones, or at a moderate estimate, 500,000 seeds.

Among birds, the worst offenders are jays and nutcrackers, which attack the immature green cones from about June onwards, and also extract the seed from the ripe cones as they open. When the cone scales are young and tender they bite them off much as the flying squirrels do, but as they become more mature and tougher, they shred them, leaving the fibrous parts; this is apparently done in the effort to open the scales and reach the immature seeds beneath. After the seeds fall they are consumed in quantity by pheasants, which are very partial to them and feed on them throughout the winter.

Considering that the seed is destroyed to such an extent, it is surprising that the tree reproduces as freely as it does; where reproduction is satisfactory, the only explanation seems to be that the seed is produced in such large quantities that there is enough to spare after satisfying the requirements of beast and bird.

GERMINATION (Fig. 403, *b-f*). Epigeous. The radicle emerges from the end of the seed and descends, the hypocotyl elongates, sometimes arching slightly, and the cotyledons, 9-12 in number, are carried above ground. As the cotyledons elongate the shell of the seed remains enclosing their apices for a time, eventually falling to the ground, when the cotyledons spread out radially in a whorl, from the centre of which the young shoot develops.

THE SEEDLING (Fig. 403). The following is a description of the natural forest seedling during the first four years, grown under average conditions:

First year (Fig. 403, *f*).—*Roots*. Primary root short to moderately long, terete, tapering, thin, somewhat delicate, brown or greenish brown; lateral roots usually absent, or if present, few and small. *Hypocotyl* distinct from the root, 1-2.5 in. long, cylindrical, thin, tender, pale green at first, becoming reddish or brownish green. *Cotyledons* 9-12, whorled, 1-1.5 in. long, acicular, triquetrous, compressed laterally, incurved when young, becoming straighter afterwards, pale green, inner edges minutely and somewhat widely serrulate. *Stem*. Natural seedlings form no stem above the cotyledons during the first season, producing at most a central tuft of primordial needles; many produce nothing more than the whorl of cotyledons, while some have scarcely completed germination. In reckoning the age of a natural seedling, therefore, the first season's growth may be taken up to the remains of the cotyledonary whorl or immediately above it. *Leaves*. Primordial single needles, if present, up to 0.75 in. long in a dense, starlike cluster in the centre of the whorl of



FIG. 403 *Pinus excelsa*—SEEDLING $\times \frac{3}{8}$

a—Seed b-f Germination and development of natural seedling to end of first season
g Natural seedling at end of second season h—Natural seedling at end of third season
i Natural seedling at end of fourth season
1, 2, 3 end of first, second and third season's growth respectively

cotyledons, acicular, acuminate, pale green or silvery bluish green. Adult needles absent.

Second year (Fig. 403, g).—*Roots*. Primary root moderately long, wiry, flexuose; lateral roots few or moderate in number, short or moderately long. *Hypocotyl* greenish brown or light brown, smooth. *Cotyledons* usually green in spring, turning brown during the season, dead and drooping or some fallen by the end of the year. *Stem* (above cotyledons) green or greenish brown, glabrous, usually attaining 0.5–1.5 in. in length. *Leaves*. Primordial needles spirally arranged, acuminate, up to 1 in. long, green, lower ones turning brown by the end of the year. Adult needles, in fascicles of five, up to 2.5 in. long, with a basal sheath of light brown scales, appear for the first time towards the apex of the shoot; fascicles more or less whorled, often in two tiers, the lower with one or two fascicles, the upper with two, three, or more. Terminal bud distinct, greenish.

Third year (Fig. 403, h).—*Roots*. Primary root moderately long, tapering, wiry; lateral roots moderate in number and length. *Hypocotyl* greenish brown, smooth, wiry or woody. *Cotyledons* usually still visible in part, dead, brown, drooping; if absent, their position marked by a distinct ring. *Stem and leaves*. Stem still comparatively thin except in specially vigorous specimens. Second year's shoot (above cotyledons) greenish grey, usually with remains of primordial needles present, these being dead and often fragmentary, thickly grouped at base of shoot; insertions of fallen needles conspicuous, whorl of fascicles of adult needles in fives, up to 3 in. long, present on upper part of shoot, some often dead, reddish-brown; living needles green, with two pale silvery blue lines on inner surface. Third year's shoot pale green, 1–2.5 in. long, with small spirally arranged scales, whose insertions after they fall are prominent in the form of raised dots; fascicles of adult needles in fives, up to 3 in. long, in axils of scales on upper part of shoot, becoming densely clustered towards the apex. Terminal winter bud greenish, with thin papery scales.

Fourth year (Fig. 403, i).—*Roots*. Primary root moderately long, tapering, considerably thickened, woody; lateral roots moderate in length and number. *Hypocotyl* (first year's shoot) fairly smooth, with occasional lenticels, greyish brown. *Cotyledons* absent, their position usually marked by slight annular markings with a cluster of dormant buds immediately above. *Stem and leaves*. Stem considerably thickened, woody. Lateral shoots often commence appearing at the nodes, representing the bases of the successive years' main shoots. Second year's shoot greenish grey to greyish brown, devoid of needles, scale insertions visible, often with dormant buds immediately above them; upper extremity of shoot marked by closer grouping of scale insertions and dormant buds, often with slight swelling. Third year's shoot silvery greyish green, marked with spiral scale insertions; upper part of shoot with spirally arranged fascicles of adult needles in fives, up to 4 in. long, closely grouped towards the apex of the shoot, basal sheath up to 0.35 in. long, with light reddish brown papery scales. Fourth year's shoot, 1–2.5 in. long, pale green to greenish grey, with spirally arranged triangular acuminate scales 0.1 in. long, or mere scale insertions; fascicles of adult needles in fives, up to 4 in. long, more silvery blue than those of previous year's shoot, densely clustered towards apex, basal sheath up to 0.5 in. long with light reddish brown papery scales. Terminal bud green, with a winter covering of pale reddish papery scales.

In the above description the dimensions given may be taken to represent those of the natural forest seedling grown under average conditions; such a seedling may be expected to attain a height of about 5 to 8 in. in four years, though under specially favourable conditions the height may be considerably more. It may be noted that there is little or no growth above the cotyledons in the first year, and that adult needles commence to form in the second year.

In counting rings on stumps at least five years should be added for the time taken for a seedling to reach stump height.

Nursery-raised seedlings, which are usually grown under much more favourable conditions, show more rapid growth and better development both of the stem and of the root-system, including usually a distinct elongation of the stem above the cotyledons during the first season, with buds of adult needles towards their apex. Nursery seedlings ordinarily reach a height of about 9 to 15 in. in three years, with stout stems and well-developed masses of adult needles (Fig. 406).

Seedlings flourish best on well-drained fresh soil with an abundance of light. They tend to damp off with an excess of moisture and to die of drought in shallow, dry soil. They are frost-hardy in their natural habitat. Under slight shade they persist for a time, but develop slowly, while under heavy shade they soon die off. Where rats are prevalent the roots of young plants are apt to be gnawed through immediately below the surface of the ground, particularly in nurseries.

SILVICULTURAL CHARACTERS. The blue pine is a strong light-demander from youth onwards. It persists under moderate shade for many years, but makes little progress, and eventually becomes completely suppressed; vigorous growth is attained only with complete overhead light. In the Ramgarh Kundi forest, Kulu, on a southerly to south-westerly aspect, I measured a number of young trees, aged twelve to fifteen years, growing completely in the open; these had an average height of 25 ft., and were particularly vigorous. In close proximity were numerous young trees under a moderately open overwood of blue pine; these young trees averaged twenty years of age for a mean height of 6 ft., and were thin and feeble. Even in fair-sized gaps the growth was poor compared with that in the open. Nevertheless young blue pine plants have a remarkable aptitude for pushing their way through shrubby growth if this is not too heavy, and on hot aspects the protection afforded by shrubs is useful. Under the shade of broad-leaved species, and particularly oak, the blue pine persists for a long time, and if the shade is light it makes its way in time through the canopy; the lopping of oak trees is specially favourable to the establishment of young blue pine.

The root-system of the blue pine is massive, though somewhat less so than that of *Pinus longifolia*; it is to some extent superficial, footpaths through blue pine forest being often covered with a network of roots. The tree is wind-firm.

The blue pine is subject to various forms of injury. It suffers more from snow than any other Himalayan conifer, the damage being of two kinds, breakage of the crowns and stems and curvature at the base of the stem. The latter, which is prevalent in many localities, is caused in youth, when the plants are still flexible, by masses of snow sliding down the hill-sides and pressing down the young plants; the leaders persist in taking a vertical course, and eventually the stem becomes strong enough to grow erect, but the base retains a pronounced curve, and the lower part of the bole, often to a length of many feet, is rendered useless as timber. Snow-break is particularly common in dense pole crops, and is aggravated if these crops are suddenly opened out after growing in a dense condition for some time. The



FIG. 404. Branch of *Pinus excelsa* in July, showing *a*, immature small terminal cones about 2 months after pollination, *b*, immature lateral cones, 1 year older than *a*, to ripen the following October; *c*, node with one stage wanting; *d*, old open cones, 3 years older than *a*. Squares show inches.



FIG. 405. Branch of *Pinus excelsa* in September, showing: *a*, immature cones about to ripen; *b*, old open cone 1 year older than *a*; *c*, old open cone 2 years older than *a*; one stage, the small terminal immature cone, wanting.



FIG. 406. *Pinus excelsa*, nursery seedlings 3 years old, Jaunsar : centre plant 2 ft. 1 in. long from top of shoot to end of root.



FIG. 407. Natural reproduction of *Pinus excelsa* springing up on abandoned cultivation ; pure forest of *Pinus excelsa* behind, Bashahr, Punjab.

best preventive measure is to commence thinnings early and to carry them out lightly and at frequent intervals.

The blue pine is very sensitive to fire, although fires are not as a rule so common in the region of this pine as they are in the hotter and drier belt below it occupied by *Pinus longifolia*; still when fires do occur the blue pine suffers more severely, since it has not the advantage of such a thick protective bark as *Pinus longifolia*. When a fire occurs, pole crops are frequently killed outright, while even large trees often succumb.

Browsing by goats causes serious injury to young blue pine, the plants acquiring a low bushy form in areas where goat browsing is permitted. Sheep and cattle are less harmful, as these animals avoid the pine if other food is plentiful, though in the case of cattle and buffaloes, particularly the latter, damage is caused by trampling. Bears and porcupines do much injury in some localities by barking the stems of poles and saplings, often ringing them completely and killing them. Porcupines remove the bark by gnawing, and bears tear it off with their teeth and claws, the damage being done chiefly in the spring. Among direct forms of injury caused by man are lopping of the branches for litter and manure and cutting out torch-wood from the base of the tree, thereby producing a large cavity to which fire is sometimes applied to stimulate the accumulation of resin. Lopping is particularly injurious in that it results in the admission of the fungus *Trametes Pini* (see below).

The only serious climber in blue pine forest is *Rosa moschata*. Among others which occur, but as a rule do comparatively little damage, are *Vitis semicordata*, *Hedera Helix*, *Clematis montana*, and *Jasminum grandiflorum*. In some localities the branches of the blue pine are attacked by the minute lorantheaceous parasite, *Arceuthobium minutissimum*, Hook. f., which does considerable injury when it occurs in quantity. Dr. Duthie found it prevalent in Kumaun and Kashmir, and I have noticed it, not on a large scale, in Hazara and in the Simla hills. It appears in the form of bright green masses and produces small excrescences on the twigs.

Among fungus pests of the blue pine by far the most serious is *Trametes Pini*, Fries, an account of which has been published by Mr. R. S. Hole.¹ This fungus attacks many coniferous species in different parts of the world; in Europe its principal host is *Pinus sylvestris*. The obvious signs of attack are (1) the rotting and disintegration of the heart-wood, rendering the timber more or less valueless and the trees liable to be broken by wind, and (2) the appearance of the sporophores on the stems or on exposed roots, at points where some injury has been inflicted and the wood has been exposed, particularly where branches have been lopped or broken off. The sporophores, which are produced chiefly during the monsoon, from July to September, and to some extent also in the early spring, are usually bracket-like, but vary much in shape; they may persist for some time, finally dropping off. Several years may elapse between the date of first infection and the production of the sporophores, and hence trees may be affected by the fungus and yet show no outward sign of it. Trees of all sizes are attacked, and the damage done in some districts is enormous, a large proportion of the trees being rendered entirely useless for timber. Although they are not ordinarily visible to the

¹ Ind. For. Records, vol. v, pt. v, 1915.

naked eye, a microscopic examination by Mr. Hole revealed numerous hyphae in the sap-wood and in the sieve-tubes of the bark. In bad cases the entire heart-wood of the stem and roots is more or less disintegrated. Mr. Hole's investigations, carried out in parts of Bashahr and the Simla hills, led to the conclusion that primary infection as a rule takes place through the stem by means of wind-carried spores, and not through the roots, though the mycelium is capable of spreading from tree to tree through the roots, where, as is often the case, natural root-grafting takes place.

The most fruitful cause of the spread of the disease in the western Himalaya is undoubtedly the practice of lopping, which is extensively carried out in many tracts. Preventive and remedial measures suggested include (1) strict prevention of lopping, cutting out torch-wood and other forms of mutilation ; (2) felling all infected trees at or below ground-level, burning the stumps or covering them with earth, burning all sporophores and unutilizable material and quickly removing what is utilizable ; (3) removal in thinnings of trees injured by snow or other causes ; (4) in badly affected areas complete removal of the crop, replacing it by deodar or broad-leaved species ; (5) in gaps caused by the removal of diseased trees, likewise replacing the blue pine by deodar or broad-leaved species ; (6) planting protective belts of species other than blue pine along the edges of blue pine forests adjoining village lands where the pine is lopped, and from which the fungus spores may spread.

Resin-tapping operations have not yet been introduced systematically in blue pine forests, and it is not yet known if they will, when introduced, result in causing a spread of *Trametes Pini*. Possibly tapping to death for a few years prior to felling may have no adverse results, but if light tapping for a long series of years is to be introduced its effects should be carefully watched before it is carried out on an extensive scale.

Peridermium brevius, Barcl., is a fungus of comparatively small importance which attacks needles, twigs, and branches of blue pine trees and stems of saplings. It appears in May and June in the form of small orange-coloured sacs of spores on the needles. In the bark form the bark becomes blistered, often with swelling of the part affected, and orange-coloured sacs of spores burst through to the surface in May and June. The fungus attacks the living cortex, rendering it at first soft and spongy and afterwards dry and brittle ; in bad attacks it encircles the stem or branch and kills the part above the point affected. I have noticed the bark form locally in Kulu and Hazara, but so far it does not appear to be widespread.

NATURAL REPRODUCTION. Wherever conditions are favourable there are few if any Himalayan trees which regenerate in such profusion as the blue pine. The factors which influence natural reproduction may be considered separately under (1) seeding conditions, (2) germination, (3) climatic conditions, (4) soil and soil covering, (5) light, (6) fire, (7) grazing.

(1) *Seeding conditions.* The seeding conditions of the blue pine are particularly favourable ; these conditions have already been dealt with, but they may be recapitulated briefly. Fertile seed commences to be produced at an early age, and sufficient seed for complete regeneration is produced at an earlier stage than in the case of *Pinus longifolia*. Good seed-years are more frequent than is the case with any other important Himalayan conifer, and

a year seldom occurs in which at least a fair proportion of the trees in a blue pine forest do not bear seed, while in good years seed is produced in large quantities. Much seed may be destroyed on the tree by jays, nutcrackers, monkeys, and flying squirrels, and on the ground by pheasants, but in spite of this the quantity produced is usually amply sufficient for purposes of regeneration. The winged seeds are shed from the end of September to the early part of November, the open cones remaining on the tree, and are carried to a considerable distance. Natural seedlings of blue pine are often found on open ground a surprisingly long distance from any seed-bearer, and it is no uncommon thing to find natural reproduction springing up in dense masses at least 200 yards from any mother tree. Blue pine saplings are constantly found appearing under broad-leaved species or in gaps in forest of deodar, spruce, or even silver fir, in places where no pine seed-bearer can be found anywhere near. In Hazara, for instance, there are numerous examples of silver fir forest, when opened out, giving place to young blue pine crops originating from seed spread from seed-bearers a considerable distance away. In deodar forests this encroachment is common in many localities. Numerous examples may be found of bare slopes becoming clothed with young blue pine crops from seed-bearers growing on the ridges far above, or widely scattered over the area.

(2) *Germination.* The seed lies on the ground through the winter and ensuing hot season, and does not germinate until the rainy season ; this is undoubtedly a disadvantage in that it is exposed for several months to the attacks of birds. Under natural conditions germination commences in warm situations in June, after the first heavy showers, and continues during the rainy season ; in cool, shady places seed may be found germinating as late as October. Seed may occasionally be found germinating inside cones which have fallen, and dense clusters of seedlings may be found in one place, having arisen from seed which has germinated in cones lying on the ground or has escaped from such cones and germinated *in situ*.

(3) *Climatic conditions.* The winter snowfall acts beneficially in protecting the seed on the ground from being devoured by birds. Owing to the late germination of the seed the seedling, unlike that of the deodar, is not exposed to the drought of the hot season during and immediately after germination. In hot, dry places, however, seedlings may die off in quantity during periods of drought following the rainy season, particularly from September to November of the first year and during the next hot season from April to June. Years of ample snowfall and rainfall are beneficial in preventing this mortality.

(4) *Soil and soil-covering.* The blue pine regenerates most freely on newly exposed loose porous soil. This is well illustrated by the remarkable manner in which it springs up on abandoned cultivation (Figs. 407 and 408), on new soil produced by landslips, and wherever the soil has been freshly exposed or deposited. In certain localities, again, dense crops of blue pine spring up on new deposits of shingle and boulders in river-beds. Micaceous loamy soil resulting from the decomposition of mica schist is particularly favourable, since it is porous, while at the same time it retains moisture. Dry, shallow, or stiff soil is unsuitable for blue pine reproduction, which fails on hot aspects where there is a mass of hard rock near the surface ; this is particularly

noticeable on limestone formations, on which the seedlings die of drought where the soil is shallow. Water-logged or very wet soil is equally unfavourable.

As regards soil-covering, the blue pine has a remarkable capacity for making its way through a growth of shrubs and even through fairly heavy weed-growth, and on hot aspects shrubby growth is most beneficial in protecting the soil from desiccation. Some plants are particularly favourable in this respect, and it cannot fail to be noticed that even on the hottest slopes, where there is a growth of bracken and *Indigofera*, the reproduction of blue pine on areas protected from fire and grazing is a foregone conclusion wherever there are seed-bearers present. *Desmodium* and *Spiraea sorbifolia* are also very favourable shrubs, as is the dwarf willow, *Salix elegans*. Among unfavourable shrubs perhaps the most typical are *Viburnum foetens* and *Parrotia Jacquemontiana*, which often cover the ground over large areas with a growth so dense as entirely to prevent natural reproduction of the pine; these weeds are particularly abundant in Hazara. Fig. 409 shows a dense growth of *Parrotia* covering a hill-side, on which pine reproduction is unable to establish itself although seed-bearers are plentiful. A dense matted growth of grass is unfavourable in preventing the roots of the pine seedlings from penetrating to the mineral soil before the young plants perish from drought; a moderate soil-covering of grass, however, is not unfavourable.

(5) *Light*. As already mentioned, the blue pine from the earliest stage is a strong light-demander, for although it is capable of persisting under moderate shade, particularly of broad-leaved species, its growth is always more vigorous with complete light. On hot aspects it is only the need for protection against desiccation that may render a protective cover of shrubs or trees advisable and even essential, but such cover should not be retained longer than is necessary. The profusion with which blue pine reproduction sometimes springs up in severely lopped oak forest is evidence of the beneficial effect of the admission of light following on the protection of the seedling in its early stages. Even in unlopped oak forest the blue pine often regenerates in quantity and succeeds in making its way through a moderately light canopy, but nevertheless its growth suffers until it has penetrated the canopy, and many plants may become entirely suppressed.

The most vigorous blue pine reproduction is always found completely in the open, granted that during the first few years protective cover may be necessary on hot aspects, particularly if the soil is dry or shallow. On bare, grassy hill-sides natural reproduction is as a rule better on northerly than on southerly aspects, but where there is a protective growth of bracken, *Indigofera*, *Desmodium*, and other favourable shrubs the pine has no difficulty in regenerating with the greatest freedom on the latter.

(6) *Fire*. Fire is probably the most adverse of all factors relating to natural reproduction, for blue pine seedlings are extremely sensitive to it, and in areas annually or periodically burnt reproduction has no chance of establishing itself. Bare hill-sides suitable for blue pine, if carefully protected from fire, fill up with young pine crops in a surprising manner where there are any seed-bearers in the neighbourhood; some of the best even-aged pole crops existing at the present day are the result of the introduction of fire-protection on bare or sparsely tree-covered hill-sides forty to fifty years ago.



FIG. 408. Pure forest of *Pinus excelsa* sprung up on old cultivated land as a result of the introduction of fire protection 40 years previously, Jaunsar.



FIG. 409. *Pinus excelsa* with a dense undergrowth of *Parrotia Jacquemontiana*, which prevents natural reproduction of the pine, Kagan valley, Hazara.



FIG. 410. Young crop of *Pinus excelsa*, up to 25 ft. in height, sprung up in a blank caused by the destruction of the overwood by a severe fire more than 20 years previously, Bashahr.

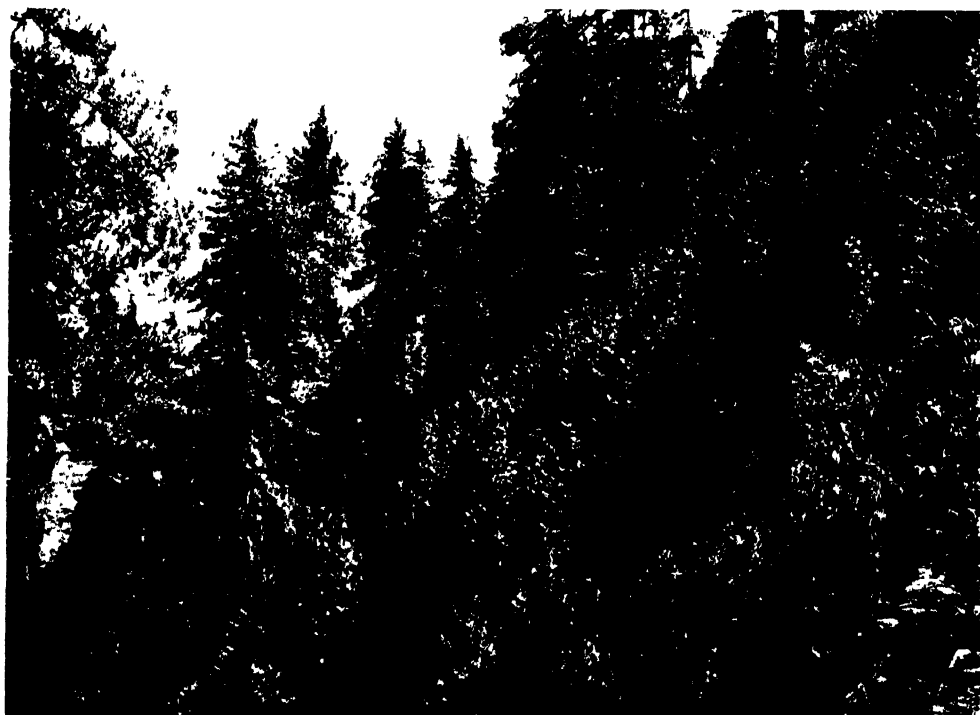


FIG. 411. Natural reproduction of *Pinus excelsa*, with some deodar, produced by an even spacing of seed-bearers to 5 or 6 trees per acre ; aspect south-west, elevation 7,500 ft., Bashahr.

One result of fire-protection is to cause the blue pine to spread downhill into the region of *Pinus longifolia* where the zones of the two pines meet, and it is not an uncommon sight in such localities to find an open overwood of *Pinus longifolia* with a young crop beneath it consisting largely of blue pine and deodar (see Fig. 450).

Although fire destroys blue pine seedlings and prevents natural reproduction, nevertheless the thorough burning of an area is often followed by profuse reproduction, owing to the action of fire in clearing the ground and producing a favourable germinating bed. Fig. 410 shows a dense natural young crop which sprang up after an intense fire; this fire occurred more than twenty years previously, destroying much of the overwood, and the charred remains of some of the overwood trees are still visible, standing over the young crop. The burning of undergrowth and felling refuse, as will be seen later, is an important regenerative measure.

(7) *Grazing.* There are few, if any, Himalayan conifers which suffer more from grazing than the blue pine. Light cattle grazing, as opposed to goat browsing, may be comparatively harmless if there is a plentiful supply of other fodder present, but as a general rule it is a safe procedure to enforce strict closure to grazing of any kind if complete reproduction is desired in the shortest time possible. Natural reproduction is often found in grazed areas, but here young seedlings are usually absent except under the shelter of shrubs, and as soon as they grow large enough to come within the reach of animals they are browsed down. The young plants stand repeated browsing for many years, but acquire a low bushy form; eventually a leader may survive and a normal plant arises from the centre of the bushy growth, the result being a tree much branched at the base.

Pine crops thus arise on grazed areas, and at first sight they may appear satisfactory, but a closer examination usually shows that the stems, instead of forming a close crop, are widely spaced and are much branched towards the base; if these stems are felled at ground-level it will be found from an examination of the annual rings in the centre that the plants have had a long struggle in youth, and for years have put on little or no growth.

Where young spruce and blue pine spring up together in grazed areas the spruce often survives at the expense of the pine, the latter being browsed down, while the spruce establishes itself and eventually suppresses and kills out the pine.

ARTIFICIAL REPRODUCTION. Direct sowing is usually considered preferable to transplanting from the nursery, as the latter requires great care in order to avoid damage to the tender rootlets, and where planting operations on a large scale are to be carried out the amount of close supervision necessary to ensure success is not always available. Successful transplanting, however, can be carried out if sufficient care is taken to plant only in wet weather and to avoid damaging the roots in any way. Nursery soil should be light and not binding, and should not be manured. The seed-beds are sown in November and protected from pheasants, and germination takes place at the commencement of the following rainy season. The usual custom is to transplant seedlings either two or three years old during the rainy season. They are pricked out about 9 in. by 6 in. during the rains a year after germination, and if plants

three years old are required they are again pricked out about 15 in. by 12 in. when two years old. They are finally planted out with balls of earth. The spacing most commonly adopted has been 5 ft. by 5 ft., or 4 ft. apart in contour lines 8 ft. to 10 ft. apart.

Direct sowing is much more usual than transplanting, and is, as already remarked, usually more successful. For sowing up abandoned fields and open places of the kind broadcast sowing is suitable. Sowing in prepared contour lines, broken or continuous, or in prepared patches, can be carried out with great success. The general lines on which this work is done are similar to those described for the deodar (see p. 1117). The quantity of seed, by weight, required to sow up a given area with blue pine is about half that required in the case of the deodar. In Kulu gaps on which undergrowth and felling refuse have been collected and burnt have been successfully sown up in the manner described for deodar. The early thinning out of excess plants in sowings is a very necessary operation ; it is usual to dig up such plants when one to two years old and use them for planting up gaps.

Blue pine seed may be sown at any time from November to early June. Where pheasants are at all plentiful it is preferable to sow in May or early June, in order to avoid exposing the seed to their attacks during the winter ; in this case soaking the seed in water for twenty-four hours is said to stimulate germination.

On favourable soil and on cool aspects blue pine sowings succeed well entirely in the open, but on hot aspects and shallow soil it is preferable, and may be necessary, to sow in the shade of bushes. Failing such natural protection artificial shades consisting of bundles of grass supported on rough tripods of sticks or pieces of ringal bamboo have been found effective.

The readiness with which blue pine springs up in the open has at times been made the plea for sowing it on bare hill-sides with shallow soil overlying hard rock such as limestone ; such efforts are foredoomed to failure, for the pine will not survive in such localities. Sowings have been made from time to time with the view of filling up blank grassy areas of this kind on hill-sides where seed-bearers are plentiful in the neighbourhood and where natural reproduction has sprung up wherever possible ; such sowings, as might be expected, have always resulted in failure, for if there are seed-bearers present, natural reproduction hardly ever fails to establish itself wherever conditions for its establishment are favourable, and blank areas in such places indicate unfavourable conditions which will similarly prevent success resulting from sowings.

SILVICULTURAL TREATMENT. The treatment of the blue pine may be considered under two heads : (1) regeneration, (2) tending.

(1) *Regeneration.* The main factors affecting the natural reproduction of the blue pine have already been dealt with. In practice, given abundance of light and protection from fire and grazing, wherever conditions for natural reproduction are favourable, the blue pine is one of the easiest of all species to regenerate. The careful selection of seed-bearers, although important, is of less consequence than in the case of *Pinus longifolia*, in which they should be chosen as far as possible from among trees with umbrella-shaped or large round crowns. The blue pine does not produce an umbrella-shaped crown,

and seeds freely from a comparatively early age. Except on hot dry slopes with shallow soil a wide spacing of seed-bearers will effect completer regeneration than in the case of the deodar, and a spacing which may be open enough for deodar may not be open enough for blue pine. As regards the method of spacing seed-bearers, experience so far has shown that the best results have been attained by an even spacing of single trees, and not by creating large gaps leaving intervening belts of forest untouched, as in the group system, for the latter method, besides being more complicated, often results in a strong growth of weeds and coarse grass in the gaps. The aim should be to produce even-aged crops, for which the blue pine is admirably adapted.

The actual spacing of seed-bearers must vary with aspect and other local conditions. As explained in the case of the deodar (p. 1121), excellent young crops of that species mixed with blue pine have been produced with a spacing of from five or six to twenty seed-bearers per acre. The former spacing, however, is ordinarily too dense for the blue pine alone. In Kulu good results have been obtained with a spacing of 60 or 70 ft., representing nine to twelve trees per acre, and generally speaking about ten seed-bearers per acre is perhaps the most suitable number to retain under ordinary conditions, though on hot slopes the number might be increased to twenty. Better results could not be wished than those shown in Fig. 411, representing blue pine forest in Bashahr with an even spacing of seed-bearers to about five trees per acre. The good reproduction shown in Fig. 412 was secured with an average spacing of about 40 ft., giving twenty-seven trees to the acre, but the overwood should have been removed some years previously, as the young crop was showing signs of suppression. The overwood should never be retained over the young crop longer than is absolutely necessary, since the latter does not require protection from the sun after the first two or three years, and grows best completely in the open. The effect on reproduction of even a moderate opening of the canopy in a comparatively young crop is illustrated by a case at Koti Kanasar in Jaunsar. A sample plot consisting of a dense even-aged crop of blue pine thirty-eight years old, averaging 2 ft. 1 in. in girth, was laid out in 1911 and thinned to 456 stems per acre. During the following winter severe snow damage opened the canopy farther. When the plot was laid out seedlings were entirely absent, but when it was again visited in 1916 the ground was covered with natural seedlings averaging 8 in. in height, particularly in gaps caused by snow-break. Probably this reproduction would not survive long without a farther opening of the canopy, but this instance demonstrates the fact that natural reproduction is capable of appearing with only a moderate opening, and in comparatively young crops.

Where deodar and blue pine are to be regenerated in mixture, a convenient method is to open the canopy moderately at first, thus securing a certain amount of deodar reproduction, and then opening out drastically with the object of filling the gaps in the young deodar crop with blue pine.

Blue pine reproduction can often be secured without difficulty by merely opening out the canopy in the manner just indicated. Where there is a heavy growth of undesirable weeds or a mass of felling refuse littering the ground, it is necessary to cut and burn the weeds and to collect and burn the felling

refuse. The details of this operation are as described for the deodar (p. 1122).

In making seeding fellings the retention of badly suppressed advance growth is useless, as such growth will not respond to the opening; vigorous groups of advance growth, however, may be retained.

Where pure blue pine crops are concerned a fairly short regeneration period should ordinarily suffice. For the Hazara blue pine forests a period of twenty years is to be adopted, though experience alone will show whether or not this will be suitable. Where blue pine and deodar are mixed a longer period is usually necessary. In the Kulu and Hazara forests where these two species are mixed, a period of thirty years is provided for; under favourable conditions, however, a period of twenty-five years would probably be found sufficient.

(2) *Tending*. Weeding in young blue pine crops is not always necessary. Where there is a growth of favourable shrubs such as *Indigofera* and *Desmodium*, or of bracken, the young pine crop makes its way through them without difficulty; where there is a dense growth of troublesome weeds such as *Viburnum foetens*, *Parrotia*, and others, however, regular weeding is necessary until the young crop is free from suppression. Thinnings present some difficulty. Even in very dense crops there is a great tendency for numerous side branches to persist. Yet if these crops are kept unthinned for any length of time and are then suddenly thinned when they have reached the pole stage, severe damage from snow-break is almost certain to occur. Thinnings should be commenced early, carried out lightly, and repeated at fairly frequent intervals, that is, not more than ten years, in order to minimize the damage from snow; in many cases thinnings from pole crops will often consist largely of the removal of snow-broken stems. Where there is any risk of fire the removal of dead and suppressed stems in sapling and pole crops, in order to prevent fire from ascending to the crowns of the trees, is of importance. Some years before the crop reaches maturity it is advisable to thin it fairly heavily in order to produce increment and to induce crown development for the production of seed. Fig. 400 shows a blue pine crop of good quality which has been finally thinned in this way.

The tending of mixed blue pine and deodar crops is a question of importance. The timber of the deodar being of more value than that of the pine, the latter has in the past been too often regarded as nothing more than the nurse of the deodar, to be cut out at all costs in order to favour it. Recently a more rational view has been taken of the respective merits of the two trees: blue pine timber has risen considerably in value, the growth of the pine is usually more rapid than that of the deodar, and its value will be further enhanced in the event of resin-tapping operations being carried out systematically. The cutting out of blue pine in deodar areas, therefore, is now carried out more cautiously than it was at one time, and the removal of large well-grown pine trees in order to favour small and possibly branchy deodar is no longer considered to be sound policy. It has often been the custom during cleaning operations in favour of the deodar to lop or girdle the pine instead of felling it. This exposes the pine to the risk of infection by *Trametes Pini*, and cannot be recommended.

STATISTICAL. (1) Bark thickness. The following figures, based on numerous measurements, may be taken approximately to represent the average bark thickness for trees of different girths :

Girth.	Bark thickness.
Under 2 ft.	0.5 in.
2 ft.-2 ft. 11 in.	0.6 in.
3 ft.-3 ft. 11 in.	0.7 in.
4 ft.-4 ft. 11 in.	0.8 in.
5 ft.-5 ft. 11 in.	0.9 in.
6 ft.-6 ft. 11 in.	1.0 in.
7 ft. and over	1.1 in.

(2) *Growth in youth.* Measurements made at different times in fifteen young plantations in Jaunsar showed the following mean growth in girth and height :

Pinus excelsa : growth in young plantations, Jaunsar.

Age. years. (from seed)	Mean girth. in.	Mean height. ft.
4	..	1.8
6	3.2	2.7
8	5.5	5.2
10	8.2	8.5
12	11.4	12.5

Under specially favourable conditions the growth in youth is much more rapid than this. Three plants in an old nursery at Koti Kanasar in Jaunsar were measured in 1887, when eleven years old from seed, and showed heights of 18 ft., 19 ft., and 28 ft.¹ As mentioned above, natural seedlings may be expected to reach a height of only about 5 to 8 in. in four years.

(3) *Girth and height increment.* After the young plant has established itself and normal increment begins, the rate of growth under favourable conditions is rapid until the tree approaches maturity, when the growth in girth usually becomes slower, while height-growth may almost cease. The blue pine is not a long-lived tree, reaching its physical maturity as a rule at 120 to 180 years, after which it often becomes unsound in the centre ; at the higher elevations and in dry climates, however, it may maintain its soundness longer, although the growth is slow. In the first half of its life the blue pine easily outstrips the deodar both in girth and in height, and vigorous young poles may exhibit an annual height-growth, judged by the length of the internodes, of as much as 3 ft., and an annual girth increment of nearly 2 in.

The table below summarizes the information available regarding the rate of growth of the blue pine in girth and height. In working plans the information is recorded in various ways, but for purposes of comparison all figures in the statement have been reduced to girth measurements over bark, while no allowance has been made for the time required for a seedling to establish itself ; hence in applying these figures in practice about five to ten years should be added to the age in order to allow for the establishment of the seedling.

¹ Notes on Forest Operations, Jaunsar, A. F. Broun, 1887.

Pinus excelsa : rate of growth in girth and height.

Mean girth.

Mean height.

Age.	Hasara.		Rawal-pindi.		Chamba.		Kulu. ⁶		Bashahr. ⁷		Simla hills.		Jaunsar.		Kashmir.		Chamba.		Jaunsar.	
	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
20	1 11	1 11	1 11	1 11	1 11	1 11	1 11	1 11	1 11	1 11	1 11	1 11	1 11	1 11	1 11	1 11	1 11	1 11	1 11	1 11
30	2 10	2 10	2 10	2 10	2 10	2 10	2 10	2 10	2 10	2 10	2 10	2 10	2 10	2 10	2 10	2 10	2 10	2 10	2 10	2 10
40	3 9	3 9	3 9	3 9	3 9	3 9	3 9	3 9	3 9	3 9	3 9	3 9	3 9	3 9	3 9	3 9	3 9	3 9	3 9	3 9
50	4 7	4 7	4 7	4 7	4 7	4 7	4 7	4 7	4 7	4 7	4 7	4 7	4 7	4 7	4 7	4 7	4 7	4 7	4 7	4 7
60	5 5	5 5	5 5	5 5	5 5	5 5	5 5	5 5	5 5	5 5	5 5	5 5	5 5	5 5	5 5	5 5	5 5	5 5	5 5	5 5
70	6 3	6 3	6 3	6 3	6 3	6 3	6 3	6 3	6 3	6 3	6 3	6 3	6 3	6 3	6 3	6 3	6 3	6 3	6 3	6 3
80	7 1	7 1	7 1	7 1	7 1	7 1	7 1	7 1	7 1	7 1	7 1	7 1	7 1	7 1	7 1	7 1	7 1	7 1	7 1	7 1
90	8 4	8 4	8 4	8 4	8 4	8 4	8 4	8 4	8 4	8 4	8 4	8 4	8 4	8 4	8 4	8 4	8 4	8 4	8 4	8 4
100	9 6	9 6	9 6	9 6	9 6	9 6	9 6	9 6	9 6	9 6	9 6	9 6	9 6	9 6	9 6	9 6	9 6	9 6	9 6	9 6
110	10 2	10 2	10 2	10 2	10 2	10 2	10 2	10 2	10 2	10 2	10 2	10 2	10 2	10 2	10 2	10 2	10 2	10 2	10 2	10 2
120	11 1	11 1	11 1	11 1	11 1	11 1	11 1	11 1	11 1	11 1	11 1	11 1	11 1	11 1	11 1	11 1	11 1	11 1	11 1	11 1
130	12 1	12 1	12 1	12 1	12 1	12 1	12 1	12 1	12 1	12 1	12 1	12 1	12 1	12 1	12 1	12 1	12 1	12 1	12 1	12 1
140	13 1	13 1	13 1	13 1	13 1	13 1	13 1	13 1	13 1	13 1	13 1	13 1	13 1	13 1	13 1	13 1	13 1	13 1	13 1	13 1
150	14 1	14 1	14 1	14 1	14 1	14 1	14 1	14 1	14 1	14 1	14 1	14 1	14 1	14 1	14 1	14 1	14 1	14 1	14 1	14 1
160	15 1	15 1	15 1	15 1	15 1	15 1	15 1	15 1	15 1	15 1	15 1	15 1	15 1	15 1	15 1	15 1	15 1	15 1	15 1	15 1
170	16 1	16 1	16 1	16 1	16 1	16 1	16 1	16 1	16 1	16 1	16 1	16 1	16 1	16 1	16 1	16 1	16 1	16 1	16 1	16 1
180	17 1	17 1	17 1	17 1	17 1	17 1	17 1	17 1	17 1	17 1	17 1	17 1	17 1	17 1	17 1	17 1	17 1	17 1	17 1	17 1
190	18 1	18 1	18 1	18 1	18 1	18 1	18 1	18 1	18 1	18 1	18 1	18 1	18 1	18 1	18 1	18 1	18 1	18 1	18 1	18 1
200	19 1	19 1	19 1	19 1	19 1	19 1	19 1	19 1	19 1	19 1	19 1	19 1	19 1	19 1	19 1	19 1	19 1	19 1	19 1	19 1

¹ Working Plan for the Dungegali and Thandiani Ranges, Hazara, A. V. Monro, 1908 (92 trees).

² Revised Working Plan for the Forests of the Murree and Kahuta Ranges, Rawalpindi Division, M. R. K. Jerram 1915 (17 trees).

³ Revised Working Plan for the Leased Forests in Pangri, Chamba State, J. H. Lacey, 1901 (14 trees).

⁴ Revised Working Plan for the Leased Forests in Pangri, Chamba State, J. H. Lacey, 1901 (14 trees).

⁵ Working Plan for the Forests of the Upper Ravi, Chamba State, C. G. Trevor, 1910 (43 trees).

⁶ Working Plan for the Forests of the Upper Ravi, Chamba State, C. G. Trevor, 1910 (43 trees).

⁷ Working Plan for the Forests of the Jubal State, E. M. Coventry, 1904.

⁸ Working Plan for the Reserved Forests of the Jubal State, E. M. Coventry, 1904.

⁹ Working Plan for the Reserved Forests of the Jubal State, E. M. Coventry, 1904.

¹⁰ Working Plan for the Jaunsar Bawar Forests, P. H. Clutterbuck, 1902.

¹¹ Working Plan for the Batot Range Forests, Riasi Division, Kashmir, Hans Raj, 1917.

Ring-countings on 49 stumps in the forests of the Kishanganga valley, Kashmir, gave an average of 9.1 rings per inch of radius, representing a mean annual girth increment of about 0.7 in.¹ In the Tehri Garhwal leased forests it is estimated that a girth of 6 ft. is attained in ninety-one years, which gives a mean annual girth increment of 0.79 in.²

(4) *Out-turn.* Figures of out-turn are at present somewhat fragmentary. Systematic measurements of sample plots in blue pine crops have been carried out for some years by the Forest Research Institute, but the results are not yet complete enough to form the basis of classification into quality classes or to enable representative yield tables to be compiled. Some out-turn figures recorded in working plans and elsewhere may be quoted here.

In the Kulu working plan of 1898 the average out-turn per tree of serviceable timber in the round, including bark, based on the results of measurements of nearly 400 trees, is given as follows :

Girth at $4\frac{1}{2}$ ft. from ground, 6–6 $\frac{1}{2}$ ft. ; volume, 65 cubic ft.

Girth at $4\frac{1}{2}$ ft. from ground, 6 $\frac{1}{2}$ –7 $\frac{1}{2}$ ft. ; volume, 89 cubic ft.

Girth at $4\frac{1}{2}$ ft. from ground, 7 $\frac{1}{2}$ –8 $\frac{1}{2}$ ft. ; volume 112 cubic ft.

Mr. C. G. Trevor has prepared the following yield table from more recent measurements in Kulu :

Pinus excelsa : yield table, Kulu.

Diameter at $4\frac{1}{2}$ ft.	Age. years.	Mean annual increment of sawn scant- ling. cub. ft.	Volume.								Average.	
			Local quality I.		Local quality II.		Local quality III.		Average.		Logs.	Scantlings.
in.			Logs.	Scantlings.	Logs.	Scantlings.	Logs.	Scantlings.	Logs.	Scantlings.		
			cub. ft.	cub. ft.	cub. ft.	cub. ft.	cub. ft.	cub. ft.	cub. ft.	cub. ft.	cub. ft.	cub. ft.
12	42	0.24	26	13	20	10	15	7	20	10		
13	45	0.27	31	15	24	12	18	8	24	12		
14	49	0.29	37	18	28	14	21	9	28	14		
15	52	0.30	43	21	32	16	24	11	32	16		
16	55	0.33	50	24	38	18	28	13	38	18		
17	60	0.35	58	28	44	21	33	15	44	21		
18	63	0.38	66	33	51	24	38	17	51	24		
19	65	0.41	76	38	59	27	44	19	59	27		
20	72	0.43	86	43	68	31	50	22	68	31		
21	77	0.45	100	48	74	35	56	25	74	35		
22	81	0.49	114	54	82	40	63	28	82	40		
23	87	0.51	126	61	93	45	70	31	93	45		
24	91	0.54	140	68	103	50	78	35	103	50		
25	97	0.57	158	75	114	55	83	39	114	55		
26	103	0.58	170	82	123	60	90	43	123	60		
27	109	0.59	183	89	133	65	97	47	133	65		
28	115	0.61	191	96	142	71	104	51	142	71		
29	121	0.63	200	102	150	77	111	55	150	77		
30	129	0.64	207	109	160	83	119	60	160	83		
31	137	0.65	215	115	168	89	127	65	168	89		
32	145	0.65	223	120	178	94	134	70	178	94		
33	155	0.64	229	126	185	99	142	75	185	99		
34	..	..	234	131	193	104	150	80	193	104		
35			238	136	202	109	159	85	202	109		
36			243	141	208	114	168	90	208	114		
37			248	145	214	118	177	93	214	118		
38			253	149	220	122	186	96	220	122		
39 and over			258	153	226	126	192	100	226	126		

¹ Working Plan for the Karnah-Drawa Forests, Kishanganga Valley, Kashmir, Rai Keshav-anand Bahadur.

² Working Plan for the Leased Deodar Forests, Tehri Garhwal, J. C. Tulloch, 1907.

The following out-turn figures are recorded in the working plan of 1901 for the Pangî forests, Chamba :

Pinus excelsa : out-turn statistics, Pangî forests, Chamba, 1901.

Number of trees.	Forest.	Mean diameter at 4½ ft.	Average length of useful bole.	Average out-turn per tree.	
		in.	ft.	Gross contents. cub. ft.	Logs. cub. ft.
100	Luj	32.2	39	177	135
100	Urnu	31.9	54	227	175
100	Pontu	32.9	52	379	236
120	Moji	31	41	164	148
380	Saichu	28	37.6	160	134

The following table of out-turn has been prepared from measurements recorded in the revised felling statement of 1917 for the same forests :

Pinus excelsa : out-turn statistics, Pangî forests, Chamba, 1917.

Dia-meter.	Corre-sponding girth.	Average out-turn.		Dia-meter.	Corre-sponding girth.	Average out-turn.	
		Logs. cub. ft.	Scantlings. cub. ft.			Logs. cub. ft.	Scantlings. cub. ft.
in.	ft. in.			in.	ft. in.		
18	4 9	48	..	32	8 5	200	110
20	5 3	58	..	34	8 11	225	123
22	5 9	75	..	36	9 5	250	136
24	6 3	98	50	38	9 11	270	149
26	6 9	123	65	40	10 6	290	160
28	7 4	150	80	42	11 0	305	170
30	7 10	175	95	..	..	..	..

In the Bashahr working plan of 1905, as a result of measurements of 1,351 trees of various exploitable sizes, the average gross volume per tree was found to be 114.1 cubic ft., giving an average volume in scantlings of 55.9 cubic ft., which represents a loss in conversion of 51 per cent.

The Kotkhair and Kotguru working plan of 1903 contains the following outturn figures :

Girth (feet)	3-1½	1½-2½	2½-3	3-3½	3½-4½	4½-5½
Solid contents, including branchwood (cub. ft.)	2	8	16	27	41	60

2. *Pinus longifolia*, Roxb. Long-leaved pine, chir pine. Vern. *Chir*, Hind. ; *Chil*, Pb. ; *Shti*, Sutlej ; *Sarol*, *sirli*, Jaunsar ; *Dhup*, Nep.

A more detailed account of this tree will be found in my note on *Pinus longifolia*, *Indian Forest Memoirs*, Silv. series, vol. i, pt. 1, 1916.

A large evergreen tree, sometimes nearly deciduous in dry localities and seasons. Branches up to middle age whorled, with verticils scarcely so well defined as those of *P. excelsa*. Crown up to middle age elongated and more or less pyramidal, afterwards becoming spreading, rounded, or umbrella-shaped, with a massive branch-system. Primordial needles solitary, 0.6 in. (in young seedlings) to 2.5 in. long, acicular, obscurely triquetrous, pale, glaucous green, sharply serrulate, minutely punctate in longitudinal lines of stomata. Adult needles in fascicles of 3, 8-13 in. long, triquetrous, with one rounded and two flat sides, light green, not glaucous, minutely but closely serrulate, densely punctate in several longitudinal lines of stomata ; basal

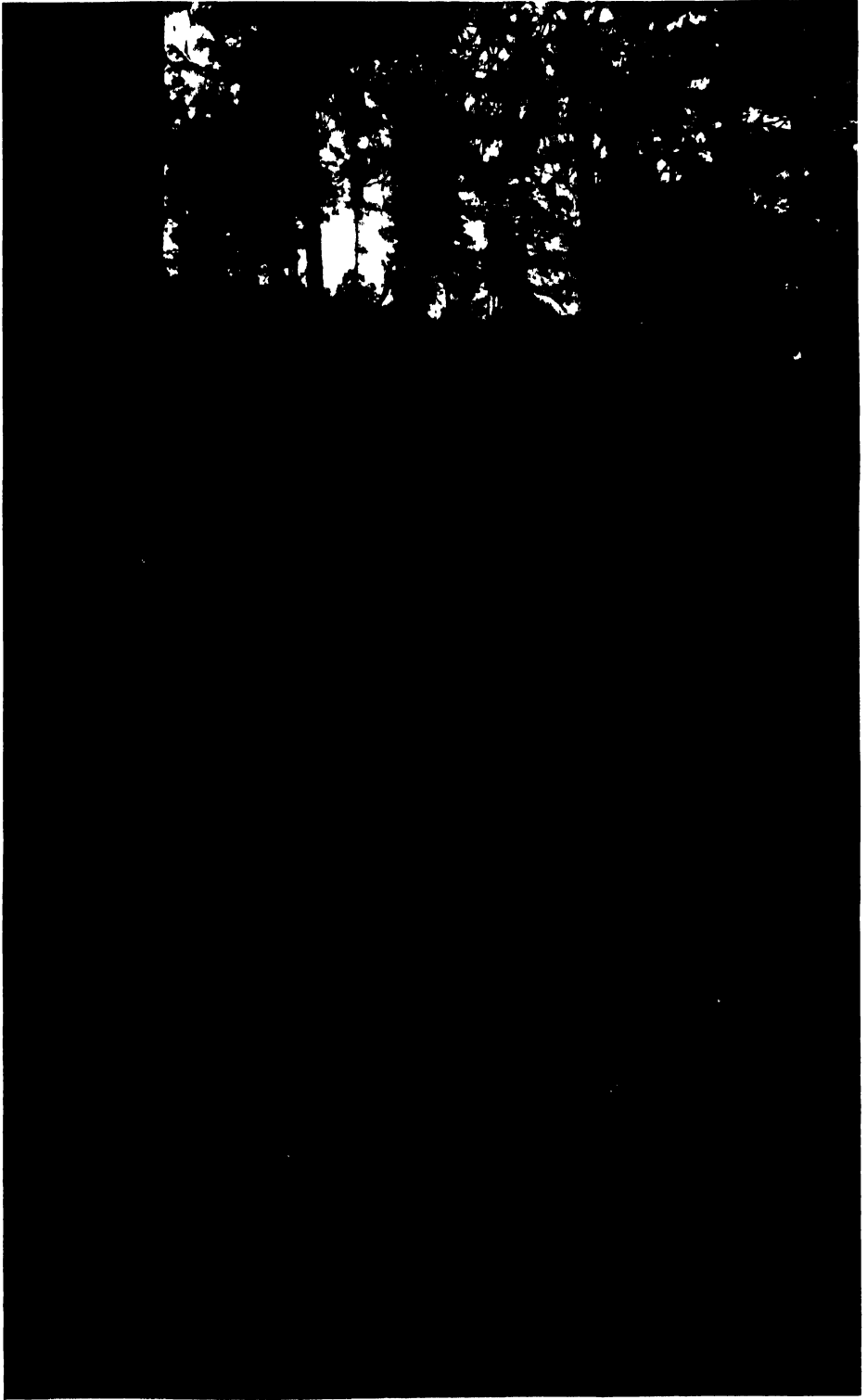


FIG. 412. Uniform regeneration felling in forest of *Pinus excelsa*, with seed-bearers spaced to an average of 40 ft., and young crop 10-20 ft. high ; overwood should have been removed some years previously, Bashahr.



FIG. 413. *Pinus longifolia* forest on gneiss, Siran range, Hazara, showing effect of light in stimulating natural reproduction ; heavily opened out on left, resulting in plentiful reproduction ; insufficiently opened out at top of slope on right, resulting in absence of reproduction.



FIG. 414. Open forest of *Pinus longifolia* on gneiss with very shallow soil ; maximum height of trees 20 ft., Kangra valley, Punjab.

sheath persistent, 0.6–1 in. long, of 10–15 imbricate chartaceous acuminate fimbriate scales, at first white or light brown, later turning grey. Needles long on vigorous trees, short in poor localities, at high elevations and on over-mature or sickly trees.

Bark of poles and immature trees dark grey, deeply fissured, exfoliating in rough longitudinally elongated plates, that of older trees with large plates up to 2 ft. or more in length by 9 in. in breadth, red turning light grey on the surface with exposure. Bark thickness varies from 0.4 in. in young saplings to an average of about 2 in. in mature trees, though not infrequently reaching 3 in. on the lower part of the stem. Detailed measurements of bark thickness are given on p. 1079. Sap-wood white. Heart-wood light reddish-brown, moderately hard, somewhat coarser than that of *P. excelsa*, with conspicuous resin-ducts, much used for building, common furniture, boxes, and general carpentry. This is the principal resin-producing pine of India. The resin is slightly inferior in quality to that of *P. excelsa*, *P. Khasya*, and *P. Merkusii*, but owing to the accessibility of the chir forests this pine is at present the only species systematically tapped. The pine-resin industry in the Punjab and the United Provinces is now in a flourishing condition, and its importance must increase considerably in future as tapping operations are extended.

Under favourable conditions the chir pine attains large dimensions and forms a straight cylindrical bole. Perhaps the largest trees to be found anywhere are those in the Tons valley of Jaunsar and Tehri Garhwal, where the following measurements have been recorded :

(1)	Height 180 ft.,	girth at breast-height 10 ft.	(W. R. Fisher, 1887).
(2)	" 178	" "	11 ft. 3 in. (W. R. Fisher, 1885).
(3)	" 175	" "	7 ft. 4 in. (F. Gleadow, 1899).
(4)	" 174	" "	8 ft. 2 in. (A. F. Broun, 1886).
(5)	" 170	" "	10 ft. 6 in. (W. R. Fisher, 1885).

In this locality trees up to 150 ft. in height are by no means uncommon, while trees are to be found with girths up to 12 ft., and exceptionally up to 14 ft. Large-sized trees are met with in the forests of the Siran valley of Hazara, where Mr. A. V. Monro in the working plan for these forests records the following two measurements :

(1)	Height 151 ft.,	girth at breast-height 7 ft. ;	volume 236 cub. ft. ;	age 118 years.	
(2)	" 149	" "	7 ft. 6 in. ;	volume 254 cub. ft. ;	age 105 years.

In the Rawalpindi forests Mr. Jerram mentions having measured a tree 145 ft. in height and 8½ ft. in girth, which is quite exceptional for that locality. Mr. C. M. McCrie in 1910 measured trees up to 115 ft. in height and 12 ft. in girth in the Binsar forest, Kumaun.

On shallow soil, exposed ridges and other unfavourable situations, the trees are stunted, with tapering and often twisted or gnarled boles, and may attain a maximum height of not more than 20 to 30 ft.

DISTRIBUTION AND HABITAT. *General distribution and types of forest.* The chir pine is found in the outer ranges and principal valleys of the Himalaya and on the ridges of the Siwalik hills flanking the Himalaya, from 1,500 to 7,500 ft. and occasionally higher, from Bhutan in the east to Afghanistan in the west. Excluding Sikkim, Bhutan, Nepal, Mandi, the frontier states and Afghanistan, this pine is roughly estimated to extend over about 3,370 square miles of country and to occur more or less gregariously over about 3,230

square miles ; the total area of chir forest, including the territories mentioned, must be considerably greater. Owing to their accessibility, however, large areas of chir forest have been destroyed in the past by cutting, lopping, and burning, and many of the existing grass-covered slopes of the outer Himalaya must have been covered at one time with pine forests.

The chir pine is a typically gregarious tree, forming pure forests of considerable extent, though it often occurs mixed with other species, particularly at its upper and lower limits. Towards its upper limits its common companions are *Cedrus Deodara*, *Pinus excelsa*, *Quercus incana*, *Rhododendron arboreum*, *Pieris ovalifolia*, *Myrica Nagi*, and various other trees ; at the higher elevations *Pinus longifolia* seeks the hotter slopes and drier spurs, on which it ascends higher than it does on cool northerly slopes, and the moister depressions and cooler slopes are occupied by its associate species, particularly oak, blue pine, or deodar. The oak mixture, shown in Fig. 340, is a useful one, as the oak, often in the form of an underwood, acts as an efficient soil-protector. Towards its lower limit the chir pine is associated with low-level species such as *Shorea robusta*, *Anogeissus latifolia*, *Ougeinia dalbergioides*, *Buchanania latifolia*, *Bauhinia retusa*, *B. variegata*, and others. The true chir belt, in which the pine occurs pure or nearly so over considerable areas, is found between the upper and lower mixed belts, its limit of elevation varying with locality and aspect. Apart from its gregariousness, the pine has a marked tendency to form even-aged crops of varying extent from small patches to extensive stretches ; this is due partly to the freedom with which it regenerates where conditions are favourable, particularly in open places, and partly to its light-demanding character, which prevents it normally from forming uneven-aged crops.

The undergrowth in *Pinus longifolia* forests varies locally. In many localities, notably in the forests of the Tons valley, there is a luxuriant growth of grass. In some of the Punjab forests at the lower elevations there is often a dense undergrowth of *Carissa spinarum* and *Dodonaea viscosa*, which gives place higher up to *Myrsine africana* and *Berberis Lycium*. In many chir forests, at elevations of 4,000 ft. and over, the undergrowth consists of a shrubby growth of *Rhododendron arboreum* and *Pieris ovalifolia*. Among other undergrowth species may be mentioned *Colebrookia oppositifolia*, *Desmodium concinnum*, *Euphorbia Royleana* (dry open places at low elevations), *Ficus palmata*, *F. Roxburghii*, *Flacourtia Ramontchi* (low elevations), *Indigofera pulchella*, *Inula Cappa*, *Lespedeza* spp., *Lonicera quinquelocularis*, *Mimosa rubicaulis*, *Phoenix humilis*, *Prinsepia utilis*, *Pyrus Pashia*, *Randia tetrasperma*, *Rhus Cotinus*, *R. parviflora*, *R. semialata*, *Rosa moschata*, *Rubus ellipticus*, and *Woodfordia floribunda* (low elevations).

Local occurrence. In Hazara the most important chir forests occur in the Siran valley from 3,000 ft., the approximate level of the Pakhli plain, to about 6,000 ft. ; these forests extend to a small extent over the watershed into the Kunhar drainage. Here the pine grows excellently on granite and gneiss with a porous sandy and gravelly soil, the trees attaining large dimensions and natural reproduction springing up in abundance wherever sufficient light is admitted. The undergrowth consists chiefly of grass and *Indigofera*. The pine is for the most part pure, though in moist ravines broad-leaved

species, including *Rhododendron arboreum*, are found; above 5,500 ft. the chir is mixed with blue pine. Owing to past treatment under the selection system these forests consist not so much of large even-aged crops as of comparatively small even-aged patches of different ages, groups of young growth springing up readily wherever there are gaps in the canopy (see Fig. 413). In the Dungagali and Thandiani ranges of Hazara the chir occurs on limestone or shale on hot aspects up to 7,000 ft.; in government forests it is very limited in quantity and is mixed chiefly with *Pinus excelsa*, while outside these forests the pine tracts have been largely cleared for grazing and cultivation. In the Khanpur range, on the outer hills of Hazara, the chir pine occurs from 2,500 ft. upwards on hard limestone with shallow soil. Here the trees as a general rule are stunted, with tapering and much-branched boles and poor height-growth, though a fair girth is reached, trees over 7 ft. in girth being not uncommon; on northerly slopes with deep fertile soil the quality of the forest is very fair. Where there is sufficient depth of soil natural reproduction is often good, though it is poor where the rock is near the surface. The chief companions of the pine are *Pistacia integerrima*, *Olea cuspidata*, *Punica Granatum*, *Bauhinia variegata*, *Ficus palmata*, and *F. Roxburghii*, while on the cooler aspects and in moist ravines are found *Quercus incana*, *Q. glauca*, *Cornus macrophylla*, and other broad-leaved trees. Among the commoner undergrowth species are *Rhus Cotinus*, *R. punjabensis*, *Dodonaea viscosa*, *Myrsine africana*, *Rosa moschata*, *Woodfordia floribunda*, and *Indigofera*.

The *Pinus longifolia* forests of the Rawalpindi district, situated on the outer Murree and Kahuta hills from below 2,000 ft. to about 6,800 ft., are of much importance owing to their accessibility. At the lowest elevations the trees are somewhat scattered on sandstone hills in scrub forest of *Acacia modesta*, *Olea cuspidata*, *Flacourtia Ramontchi*, *Bauhinia variegata*, and other species. Pure chir forests commence at about 2,500 ft. and ascend to about 5,000 ft. on northern and 5,500 ft. on southern aspects; above this the chir is mixed with *Pinus excelsa*, *Quercus incana*, and other species. The undergrowth, which is sometimes dense, consists chiefly of *Dodonaea viscosa* and *Carissa spinarum* at the lower elevations and *Myrsine africana* and *Berberis Lycium* higher up; often there is little or no undergrowth. The underlying rock is tertiary sandstone with bands of clay; the sandstone is easily disintegrated and much of the sand is washed away, leaving the more adhesive clay. The resulting soil, often containing as it does an excess of clay, is not altogether favourable for the growth of chir, and the general quality of the forest is therefore inferior to that of the Siran forests of Hazara. Nevertheless in favourable situations the trees attain very fair dimensions. Fig. 436 shows a crop of good quality approaching full height-growth. A portion of the area is occupied by open stunted forest of excessively poor quality growing on bare sandstone rocks on gentle slopes, where the pine is able to exist only by gaining a footing in occasional joints in the rock. In the Rawalpindi forests natural reproduction is somewhat uncertain owing partly to the difficulty of protecting the forests from fire, partly to excessive grazing, and partly to the exposure of the seedlings in certain places to a hot sun on a rather bare stiff soil.

In the lower parts of Kashmir proper there are a few square miles of chir

forest in which the trees are of good quality, though the forests themselves have suffered from neglect. The area of chir forest in Jammu and Poonch is estimated to be slightly over 1,000 square miles. These forests are situated in the outer hills, descending to 2,000 ft. or even lower and ascending to about 6,000 ft. ; below 3,000 ft. the trees are for the most part stunted and crooked. The general condition of the forests is poor ; the best trees are found in the northern part of Riasi, but the stock is open and the forests are intersected by cultivation. Most of the Jammu forests have only recently been demarcated and brought under control ; near water-ways and large areas of cultivation they have been overworked and subjected to indiscriminate burning, and are therefore not well stocked. In Poonch the condition of the forests is very similar, but they have been under fire-protection since about 1900, and regeneration is in most places satisfactory.

In the Kangra forest division chir forests are scattered over the outer Siwalik hills, in the Kangra valley and on the lower slopes of the main range forming the boundary with Chamba, at elevations of 1,800 to over 6,000 ft. The majority of the forests are pure, and are in the pole stage, the area of mature crops being comparatively small ; the best crops are found in the Hamirpur range at an elevation of 2,600 to 3,500 ft. In a few places in the outer hills the pine is mixed with *Shorea robusta*, the latter being chiefly in the form of an underwood. In the Kangra valley at low elevations it is associated with various low-level species, such as *Dalbergia Sissoo*, *Acacia Catechu*, *Albizzia stipulata*, *Malilotus philippinensis*, *Anogeissus latifolia*, *Ehretia acuminata*, *Bauhinia variegata*, *Zizyphus Jujuba*, *Z. Xylopyrus*, and others, sometimes with an undergrowth of *Woodfordia floribunda*, *Dodonaea viscosa*, or *Cariassa spinarum*. At about 4,300 ft. an undergrowth of *Rhododendron arboreum* and *Pieris ovalifolia* begins to appear. The upper limit of pure chir is about 5,500 ft. on southerly aspects and somewhat lower on northerly aspects ; at the higher elevations the pine is mixed with *Quercus incana*. On low, hot hills in the Kangra valley, on rocky ground with shallow soil, a very poor open type of forest is met with, the trees being stunted, with a height scarcely exceeding 20 ft. (Fig. 414).

In Chamba *Pinus longifolia* occurs, usually pure, on the outer hills at 3,000 to 4,500 ft. in the south-west corner of the state adjoining the Kangra district, in the Dalhousie range chiefly at 4,000–5,000 ft., and in the lower valleys of the upper Ravi forests, where it is mixed with *Quercus incana*. The growth is slow and the trees do not reach large dimensions, while the forests are heavily grazed.

In Kulu *Pinus longifolia* forests occur in the outer Saraj, in the Sainj and Tirthan valleys, on both banks of the Parbatti up to Manikarn, and to a limited extent in the Hurla and lower Beas valleys. The forests are found at elevations of 3,500 ft. to nearly 7,000 ft. near Manikarn ; elsewhere they seldom occur above 6,000 ft. They are for the most part pure and are usually somewhat open. In some localities, notably in the Tirthan and Parbatti valleys, the chir trees reach very fair dimensions. Where excessive grazing is not practised reproduction is generally good, but in many places it is kept down by grazing. In parts of the Rupi working circle the pine is associated with deodar, while in the Tirthan valley it is occasionally mixed with blue pine. Most of the chir

forests are situated on quartzite, while in some cases the underlying rock is mica schist.

In the leased forests of Bashahr *Pinus longifolia* occurs at elevations of 4,000 to 6,500 ft. in the Nogli, Taranda, Pandrabis, and Pabar ranges ; in certain localities the trees are found scattered up to about 7,800 ft. on hot aspects. The forests are situated for the most part on quartzite or mica schist, and are sometimes of very good quality, the trees attaining large dimensions. The forests are pure up to about 5,500 ft. on northerly and 6,000 ft. on southerly aspects, above which the chir is associated with blue pine, oak, and other broad-leaved species. Where fire-protection has been successful and grazing is not excessive, natural reproduction as a rule springs up in abundance.

In the Simla hills *Pinus longifolia* occurs in various localities at suitable elevations. In the Simla municipal forests it is found in crops which are for the most part pure at the lower elevations but somewhat irregular. The growth is usually inferior, owing largely to past maltreatment ; reproduction is generally fairly good. At the upper elevations (about 6,000 ft. and over) the chir pine is mixed with blue pine, deodar, and oak. In Kotguru the pine grows on warm slopes up to 6,500 ft. ; it is rare in Kotkhai. In the Jubal state it forms very open forests, intersected by cultivation, on steep slopes up to an elevation of 5,600 ft. These forests have been annually burnt in the past, and contain little except trees of the larger classes. Fire-protection has been introduced in the case of certain areas within recent years.

In the Mandi state many of the hills have been denuded of forests, but a fair extent of chir forest is still left, though much of it is very open, and many of the areas consist of scattered trees rather than forests. The chir forests extend up to about 6,000 ft. As a rule natural reproduction is poor, owing largely to excessive grazing, but there are certain areas where the grazing is limited, and here reproduction springs up in quantity. At the higher elevations and on cool aspects the pine is mixed with *Quercus incana* and locally with *Q. glauca*. The geology varies : the rocks consist chiefly of schist, shale, and quartzite, with occasional sandstone and conglomerate.

The Chakrata forest division comprises the forests of Jaunsar-Bawar and the leased forests of Tehri Garhwal state. The *Pinus longifolia* forests of this tract occupy considerable areas in the valley of the Tons river and its feeders, the chief of which are the Rupin and the Pabar, at elevations of 3,000 ft. and upwards. The forests are situated for the most part on steep mountain slopes rising many thousands of feet from the river valleys. The upper limit of gregarious chir forest may be placed generally at 6,500 ft., though the tree is found scattered on warm aspects up to 7,500 ft. or even higher. At the lower elevations the forests are usually pure, but as the elevation increases the pine becomes mixed with *Quercus incana*, the latter species at first occupying the moister ravines and the pine the intervening spurs. From about 5,000 ft. upwards the forest is usually a mixed one of chir pine, oak, *Rhododendron arboreum*, and *Pieris ovalifolia*. Near its upper limit the chir is frequently mixed with blue pine and deodar.

The quality of the forest varies, the trees being stunted on rocky ground and shallow soils, while in favourable localities they reach a size probably

unequaled anywhere else. A considerable proportion of these forests consists of a rather open crop of mature or nearly mature trees ; where fire-protection is enforced, however, there is little difficulty in obtaining natural reproduction if the crop is opened out sufficiently, and such measures have resulted in promising crops of young growth (see Fig. 430). A luxuriant growth of grass covers the ground in most of the chir forests of the Tons valley. Grazing is nowhere very heavy ; near villages there is a certain amount of light grazing, particularly in Jaunsar proper, but in the leased Tehri Garhwal forests there is comparatively little.

Apart from the leased forests of the Tehri Garhwal state, which form part of the Chakrata division, this state is estimated to contain 368,000 acres of *Pinus longifolia* forest, situated in the valleys of the Tons, Jumna, Bhagirathi, Bhilangna, and Kaliganga. In the Tons valley the important chir forests are all leased to the British Government ; these contain some timber crops of exceptionally fine quality, whose future maintenance and improvement is assured by systematic management. In the Jumna valley the forest has been largely denuded, and the chir forests are, with the exception of some at the top of the Kameldagadh, of very poor quality with but scanty reproduction. In the Bhagirathi valley there is some good chir forest on the left bank, but elsewhere the forest has been maltreated to a large extent, although reproduction is promising where steps are taken to save it. The Bhilangna valley, from about 30 miles below the glacier down to the mouth of the Balkhela river, contains some of the best chir forest in the state. In the Kaliganga basin there is some fairly good forest in the lower portion of the Lastargadh valley. The general condition of the unleased forests is, with a few exceptions, what might be expected in the case where fellings for the supply of timber to free-grantees have often been excessive, while fires have greatly increased the damage done. These conditions account for the fact that the majority of the forests are insufficiently stocked and are not so even aged as chir forest usually is. On the other hand, the pine is, if anything, tending to spread into the oak forests. The latter have been subjected to excessive maltreatment in the way of lopping and browsing, and are tending to disappear in many places ; in such cases chir regeneration frequently appears on the ground, taking the place of the oak.

In the Dehra Dun neighbourhood *Pinus longifolia* forests occupy some of the outer ranges of the Himalaya overlooking the eastern Dun ; most of these forests are in Tehri Garhwal state, the area in British territory being represented by less than 100 acres of forest in the Malkot hills, at an elevation of about 4,500 to 6,500 ft. In and around the station of Dehra Dun, the chir pine has been largely planted and thrives well ; the elevation here is about 2,000 to 2,300 ft.

In the Saharanpur Siwaliks, a low range of hills formed of tertiary sandstone and conglomerate, and separated from the main Himalayan range by the Dehra Dun valley, chir pine is found scattered over the main ridges and spurs from the highest point (3,140 ft.) downwards, descending occasionally to the level of the main watercourses, where the elevation is about 1,500 ft. Large trees are found chiefly on the higher ridges, the lower slopes and spurs being occupied by saplings and poles, which have sprung up as a result of fire-



FIG. 415. *Pinus longifolia* forest on bare quartzite rocks, Tons valley, Chakrata division, United Provinces.

protection. In the Siwaliks the chir pine does not form extensive pure crops, but is found mixed with various broad-leaved species, of which the chief are *Anogeissus latifolia*, *Buchanania latifolia*, *Ougeinia dalbergioides*, *Shorea robusta*, *Stereospermum suaveolens*, *Terminalia tomentosa*, *Wendlandia exserta*, and the palm *Phoenix humilis*.

In the outer hills stretching from the Ganges to the Sarda, a distance of 150 miles, *Pinus longifolia* occurs in greater or less abundance on many of the ridges and spurs, descending into the valleys in some localities, notably in the Nandhaur and Sara valleys and the Chaukam Dun. Its lowest limit is about 1,500 ft. It is convenient to separate these forests of the outer hills from the main *Pinus longifolia* forests of the Garhwal and Kumaun hills, because the latter comprise the typically gregarious chir forests of the Himalaya, whereas in the outer hills, up to an elevation varying from 3,500 to 4,500 ft. and even higher, where pure chir forests commence, the pine is found either in pure patches of limited extent or mixed with various broad-leaved species, such as *Shorea robusta*, *Anogeissus latifolia*, *Terminalia tomentosa*, *Buchanania latifolia*, *Bauhinia retusa*, *Ougeinia dalbergioides*, *Engelhardtia Colebrookiana*, and others. Fire-protection has caused the pine to spread extensively.

In the great mass of the Garhwal and Kumaun Himalaya, in which the chir pine is pure or mixed with hill species—as distinct from the outer hills just referred to, in which it is more or less scattered in mixed forests of low-level species—the pine forests extend over a large extent of hilly country at elevations of 3,500 to 7,000 ft. On northern aspects pure chir forests occur mainly at elevations of 3,500 to 5,500 ft., above which the pine is mixed with *Quercus incana*, with or without *Rhododendron arboreum*; on southern aspects the limits are broadly speaking 500 ft. higher, though in each case the figures should be taken as only roughly approximate, since variations occur according to local conditions. In the inner valleys below 4,000 ft. the pine is often associated with miscellaneous species such as *Ougeinia dalbergioides*, *Bauhinia retusa*, *Engelhardtia Colebrookiana*, *Machilus odoratissima*, and others. The geology of this tract presents considerable variation. The outer hills below Naini Tal are composed largely of tertiary sandstone. The Lansdowne hills are formed of mica schist, with occasional slate, limestone, and gneiss. The Himalayan rocks of Naini Tal, Ranikhet, and Almora consist of mica schist, shale, quartzite, and gneiss, while limestone occurs locally. With this variation in the geological formations, there is considerable variation in the types and qualities of forest met with. Although the average quality of the forest is perhaps hardly equal to that of the Chakrata division, on favourable situations the trees reach large dimensions, while in many localities the loose micaceous or sandy soil is very favourable to natural reproduction.

Among the poorer types of chir forest in this region may be mentioned those in which 'twisted fibre' is prevalent, the trees often being stunted as well as twisted. Some remarks on this phenomenon will be found on pp. 1056–1061.

No accurate information is available regarding the chir forests of Nepal. Pundit Sadanand Gairola, who reported on the *tarai* forests of that state, mentions that he occasionally came across chir trees at elevations where the sal ended; from accounts which he heard, and judging from the drift-wood

found along the rivers, he concluded that there are at least some extensive chir forests in the hills.

In Sikkim, according to Gamble, the forest is not always pure, but the pine is much mixed with sal and other trees, and has the appearance of being slowly driven out.

In Bhutan Mr. Jacob¹ states that *Pinus longifolia* does not appear to grow west of the high ridge between the Raidak and Sankos valleys. East of that ridge it is very common, growing as low as 2,000 ft. and ascending to 6,000 ft., though occurring chiefly between 3,000 and 5,000 ft. In the outer hills the forests have been much denuded; those of the inner hills are in a somewhat better condition, but here also they have suffered from maltreatment and clearing for cultivation.

Mr. Jacob states that in the inner hills the forests of *Pinus longifolia* usually alternate with broad-leaved forest, the former occupying the ridges and drier slopes, and the latter the ravines and damper situations; the pine forests are invariably open and grassy, and when pure have little or no undergrowth except for a species of small palm, 2 to 3 ft. high, which is common in some forests; the only tree associated to any extent with the pine is *Quercus Griffithii*, though other oaks and chestnuts are occasionally found. There are few trees over 6 ft. in girth, but this is probably due to the extraction of large trees for building purposes. The forests are habitually burnt, with the result that most of the larger trees are unsound at the base; in spite of this reproduction is good.

In Bengal the chir pine is found in the Darjeeling district over an area of about 50 acres mixed with sal on the upper ridge of the Badamtan block on the right bank of the Great Ranjit river adjoining Sikkim. The elevation is about 2,000 ft., and the rock is mica schist, furnishing a micaceous sandy soil.

Climate. Within the natural region of *Pinus longifolia* the absolute maximum shade temperature at the lowest elevations, for instance in some of the hot valleys of the Rawalpindi district, is probably about 115° F.; in the pure chir zone, however, the absolute maximum probably varies from 90° to slightly over 100° F. The absolute minimum shade temperature within most parts of the region of the pine habitually falls below freezing-point. The normal rainfall varies from about 35 in. to 117 in. (at Dharmasala). Of twenty-three stations in the neighbourhood of the chir zone no fewer than fifteen have a rainfall between 40 and 70 in., while in the Tons valley, where the pine reaches its finest development, the rainfall is probably about 40 in. or in places even less. Within the region of the pine the great bulk of the rain falls during the monsoon, that is, from the end of June or beginning of July to September, after which there is usually a period of dry weather till the winter rains, which occur from December to February or early March; from March to June there are occasional showers of rain, often accompanied by thunderstorms. In the winter months there are occasional falls of snow towards the upper limit of the pine, but heavy falls are not common. The tree is grown successfully on the plains in places with a hotter and drier climate than it experiences in its natural habitat, for instance at Lahore and Rawalpindi, with absolute maximum

¹ Report on the Forests of Bhutan bordering on the Boundary of Eastern Bengal and Assam, W. R. Le G. Jacob, 1912.

shade temperatures of 120° and 118° F., and normal rainfalls of 18 in. and 32 in. respectively.

Geology and soil. The chir pine is found naturally on a variety of geological formations. In the outer Himalaya and the Siwalik hills it occurs on tertiary sandstone with occasional bands of clay or beds of conglomerate. In the Himalayan valleys considerable stretches of chir forest are found on quartzite; here the trees often attain large dimensions. Other common Himalayan formations on which the tree occurs frequently are mica schist, gneiss, and shales, often with bands of quartzite. In certain localities, for example in the Khanpur range of Hazara and locally in the Kumaun Himalaya, it is found on limestone; many of the important limestone tracts of the Himalaya, however, lie above the chir zone. Depth and porosity of soil have a most important effect on the growth of *Pinus longifolia*, as of other species. In Dehra Dun a chir seedling planted on a mound of loose new earth grew to a height of 20 ft. in four years. To the same factors are due the exceptional growth seen on deep boulder formations in river valleys, notably in the Tons valley; the consistency and depth of the soil and subsoil, in fact, appear to have more effect on the growth of the trees and on natural reproduction than the underlying rock.

The chir pine will grow on bare rock to an extent seldom seen in other species, but the trees in such localities are often stunted and gnarled. Reference has already been made to types of open stunted forest in the Rawalpindi district on bare sandstone rock with no soil whatever, and in the Kangra valley, where the pine occurs on gneiss, schist, and sandstone, with a very scanty surface soil consisting mainly of gneiss boulders in a stiff clayey matrix (Fig. 414). On the other hand, chir trees of very fair quality may be found growing on bare quartzite rocks, as in parts of the Tons valley (Fig. 415); here, however, the roots are able to penetrate to a considerable depth into the joints of the rock, and to find sufficient sustenance there.

On quartzite the chir forests are as a rule remarkably pure, other species occurring mainly in the moister depressions. This is apparently due to the fact that the soil and subsoil, while containing sufficient moisture for the establishment and maintenance of the pine, are too dry to support the majority of species. In the Tirthan valley, Kulu, a somewhat dry quartzite formation is found above mica schist with a moist soil; the mica schist is monopolized by blue pine, with oak and other trees, while the chir pine covers the quartzite area at a higher elevation than the blue pine. The geological formation here has a direct effect on the local distribution of the two pines, since the blue pine occurs normally at higher elevations than the chir. On mica schist with a deep moist soil the chir pine is often found mixed with oak and other broad-leaved species, and attains large dimensions under these favourable conditions. The limestone hills of the Khanpur range, Hazara, are not favourable to chir pine, the trees being as a rule stunted; this, however, appears to be due not to the presence of lime, but to the hardness of the rock and shallowness and dryness of the soil overlying it, since forest of very fair quality is to be found on northerly slopes where there is sufficient depth of soil. On the softer limestones of Garhwal and Kumaun the chir grows well where the soil is not too shallow. In the Naini Tal hills chir is only occasionally found on dolomite,

but it does not grow well on this formation ; dolomite is here characterized, as a rule, by the absence of chir.

On the Supkhar plateau of the Balaghat district, Central Provinces, chir sowings have proved successful on a sandy loam derived from the decomposition of laterite with several feet of subsoil. On fertile arable land, as at Dehra Dun, the growth is rapid provided the soil is porous and well drained.

LEAF-SHEDDING, FLOWERING, AND FRUITING. *Growth and persistence of needles.* As a general rule the needles of the chir pine persist for about one year and five months, more or less, including the whole period from the sprouting of the buds in January to the shedding of the needles in May or June of the following year. In a large number of cases, however, and particularly, though not exclusively, where vigorous saplings and poles are concerned, they persist in whole or in part for a second year, while exceptional cases have been observed where they remain for a third year. In dry, hot localities and in exceptionally dry seasons the trees are nearly deciduous, and in very dry years trees which ordinarily retain their mature needles for a second year may shed all except the new ones of the current year, causing an abnormal fall of needles.

The resting period of the chir pine is short. The winter buds form in October or November, and growth ceases till December or early January, when the new shoots begin to appear. At low elevations suppressed trees and lower suppressed branches may begin to shed their old needles as early as the beginning of March, but normally the needles do not begin to fall in any quantity till April or May, and by the end of June most, if not all, have fallen, though in some cases a few may continue to fall during July. In hot, dry seasons the needles fall earlier than they do in cool, wet seasons. While the old needles are falling the new ones lengthen rapidly, and by the time the former have fallen the latter are 3 to 5 in. long, and still erect. At this time in the case of trees which are approaching maturity the new needles are grouped in stiff tufts resembling tar-brushes (Fig. 417, *a*), and in the month of June the trees have a characteristic bare appearance, though this is not so marked in vigorous saplings and poles. Fig. 426 shows the appearance in June of mature trees and vigorous saplings respectively.

From July onwards the new needles continue to lengthen rapidly, and by September they have reached their full length, and the majority, if not all, are drooping, though often some of the upper needles remain permanently more or less erect. In October or November the terminal light reddish brown winter bud forms, and growth ceases till December or early January.

Male flowers. The male flowers, 0.5–0.7 in. long when ripening, cylindrical ovoid, subtended by protruding light brown acuminate scales with fimbriate margins, are grouped on the axis of the new shoots in spirals of 8×5, the whole inflorescence being 1–4 in. long by 1.5–2 in. in diameter (Fig. 416, *a*, *b*). The flowers are yellowish green before ripening, turning light reddish brown after the pollen is shed. At low elevations the male inflorescence is distinctly visible by the beginning of January. The flowers ripen, and pollen showers take place, from February to April, according to altitude and season. Wet, cold weather retards the escape of pollen, while hot, dry weather accelerates it. The flowers on the south side of the tree usually ripen before those on the north side. After the pollen escapes the flowers elongate to nearly 1 in. The



FIG. 416. *Pinus longifolia*—MALE AND FEMALE FLOWERS AND YOUNG CONES OF FIRST YEAR $\times \frac{3}{4}$
 a—Male flowers immediately before shedding pollen (February-April) b—Male flowers after shedding pollen (March-April) c—Male flowers after shedding pollen, catkins nearly all fallen off (March-April)
 d—Single male flower, after falling (March-April) e—Female flowers on first appearance (February-March) f—Female flowers, some days later (March) g—Young cones, two whorls of three each (March) h—Young cones, somewhat more developed (end of March-April)
 NOTE—In Figs a, b, c, e and f the needles of last year are shown cut off

male inflorescences are generally more numerous on the central and lower branches than on the upper parts of the tree. Pollen is produced in large quantities, ensuring fertilization by the agency of wind. The flowers remain on the shoot for a short time after shedding the pollen, when they fall off one by one, leaving the pale green axis destitute of any covering except the persistent recurved triangular bases of the scales which subtend the flowers (Fig. 416, c); the upper parts of these scales fall with the flowers. The axis soon changes from pale green to light reddish brown. The corresponding axis of the previous year is still distinguishable, the remains of the triangular scale-bases being visible. From the middle of March (at the lower elevations) and for some weeks afterwards, the ground near the trees is strewn with the fallen male flowers (Fig. 416, d).

Female flowers, and development of cones. The female flowers, pale green, or slightly purplish at first, are found at or near the apices of the new shoots, either solitary or in pairs or in one or two whorls of three each. Fig. 416, e, shows the female flowers at first appearance, that is, in the early part of February at low elevations, and somewhat later at higher elevations. The development of the young cones during the first month is shown in Fig. 416, f-h. The young cones are erect and ovoid, with scales arranged in spirals of 8×5 . Pollination takes place from February to April, according to altitude and weather; within a month of pollination the young cones increase to about 0.6-0.8 in. in length. They remain green during the greater part of the first season, increasing somewhat in thickness but not much in length (Fig. 417, a). About the end of October they are 0.7-1 in. long by 0.6-0.8 in. in diameter, and turn greyish brown outside, remaining green inside; they are fairly soft, and are easily cut with a knife. By this time a light reddish brown bud has formed at the end of the shoot; the cones are at the base of this bud, and are pushed out of their erect position into a more horizontal one (Fig. 417, b). In this stage the cones pass the winter. The new needles are now full-sized, and envelop the young cones, which are difficult to see on the trees.

Shortly after pollination the cone scales close. A preliminary microscopic examination, by Mr. G. H. Alington, of young cones collected in the end of June, about three months after pollination, revealed the fact that the pollen grains had entered the micropyle of the ovules and lodged on the nucellus, though no sign of the development of pollen-tubes could be detected. This would indicate that the chir conforms to the normal conditions of the genus *Pinus*, in which the pollen tube, though it commences its growth during the first season, does not complete it and fertilize the oosphere until the second year.

At the beginning of the second season the young cones again become active and turn green, the brown portion (the remains of the winter stage) being pushed to the tips of the scales. The growth from now onwards is very rapid. At the lower elevations by the beginning of March the one-year-old cones are green, 1-1.8 in. long by 1-1.5 in. in diameter, with soft not conspicuously recurved scales with brown tips. These cones are found at the base of the new season's shoot (Fig. 417, c); one or more may be found on the same shoot. By the middle of April they are 3-4 in. long, green, with scales already becoming recurved and the general shape of the cone beginning to resemble that of the mature cone (Fig. 417, d); the scales are soft and easily cut with a knife.

By June or July the cone has reached full size, but is still green (Fig. 417, e). Towards the beginning of winter the cones gradually turn brown and hard ; they are now fully developed, and in this stage they pass the winter.

The dates given above refer to low elevations ; at higher elevations the cones may be as much as six weeks later in developing.

In the spring of the third season, twenty-four months after the appearance of the female flower, the cones are light brown, 4.5–8 in. long by 2.5–3.5 in. in diameter near the base, elongate-ovoid, on short stout stalks ; the scales are hard, thick, reflexed, and tightly closed (Fig. 418, a). These cones, solitary or in clusters of two to six, are found at the base of last year's needle-covered shoot ; the portion of the shoot immediately below is usually leafless, or in cases where the needles persist for two seasons, is partially or wholly needle-covered.

The cones begin to open as a rule in April or May, but sometimes as early as March. They open only in dry weather, closing up again with rain ; given sunny weather, however, complete opening takes place rapidly. The seed does not all fall at once, but may take two or three weeks, or even more, to escape completely ; in cool localities and after rainy weather the seed may not be shed till June, while some of it may remain unshed till July. Even in fine weather there is some delay in the escape of the seeds owing to the fact that a good shaking by the breeze is required to dislodge them all ; their escape is also retarded by the fact that the cones are attached to the branches at various angles, some being more or less pendulous, some horizontal, and some inclining upwards. The fact that the seed is not all dislodged without the help of a fairly stiff breeze ensures its spread to a distance from the tree. Fig. 418, b, shows a cone at the time of opening.

From the foregoing details it will be seen that the period elapsing from the first appearance of the young female cones till the mature cones open and shed their seed is about twenty-six or twenty-seven months.

The time for which the open cones remain on the tree after shedding their seed depends largely on the weather. Some are blown down during the storms preceding the monsoon, and others in the autumn storms. A certain number remain on the tree for a year ; if they remain longer they usually disintegrate by degrees, only remnants persisting. The age of these remnants can be deduced by counting the number of years of growth on the branch, as exhibited by the rings left by former bud-scales. The open cones are sometimes of large size, as much as 8 in. by 6 in. After heavy rain they frequently close up, whether on the tree or on the ground, but open again after a few days of sunshine. Fig. 418, e, shows an old empty cone.

Succession of cones and flowers. Male inflorescences may follow each other in successive years on the same branch. Female cones may succeed female cones at intervals of one or more years ; Fig. 420 shows cones of three successive years on one branch. Male flowers may succeed female flowers on the same shoot at intervals of one or more years ; no case has yet been observed of males and females of the same year on the same shoot.

Seed and seeding. The winged seeds lie in pairs at the base of each cone-scale. Fig. 418, c, shows a detached scale with a pair of seeds in position. The seeds (Fig. 418, d), including the wing, are 1.1–1.8 in. long, the wing being 0.3–0.4 in. wide ; without the wing they measure 0.3–0.5 in. by 0.2–0.25 in.



FIG. 417. *Pinus longifolia* - DEVELOPMENT OF CONES DURING FIRST YEAR (continued)
AND SECOND YEAR $\times \frac{1}{4}$

- a - Young cones of first year, July (needles removed in front of cones, to show latter);
- b - Young cones, end of first season, November-December
- c - Immature cone early in second year, March, about 12 months from first appearance
- d - Immature cone during second year, April, May, about 13-14 months from first appearance
- e - Immature cone during second year, July, about 16 months from first appearance

In samples of seed collected from 36 different trees the number of seeds per ounce varied from 192 to 704, and averaged 358. A fair average may be taken at 350 seeds per ounce. The specific gravity of well-formed seed appears to have no relation to its fertility; in tests carried out with the samples in question the lightest seed of all had a fertility of 100 per cent., while some of the heavier samples also had a high germinative power.

An examination of 284 cones gave an average of 51 seeds per cone, the actual number varying from 31 to 105; the number of malformed seeds was remarkably small, there being an average of less than one such seed to every four cones. Mr. Jerram states that the normal average number of fertile seeds per cone from mature trees in the Rawalpindi district is 38, but that in very large over-mature trees the average is often much below this.

The age of production of fertile seed depends largely on local environment factors. Under ordinary forest conditions it is probable that few chir trees produce cones at an earlier stage than thirty years, and then only sparingly, while it is by no means unusual to find trees forty years old or more with no sign of ever having borne them. Vigorous trees in the open yield seed earlier than trees grown in close canopy or suppressed trees. In the Mandi state, at 4,500 ft., a vigorous young tree only twenty years old was observed bearing a well-developed cone. At Dehra Dun a plantation on good arable land commenced to regenerate naturally on open hoed ground round its edge in 1913; the trees were then thirty years old, and averaged 79 ft. in height and 3 ft. 3 in. in girth. In 1911 a plantation thirty-five years old in Baldhoti block, Almora, was noticed to be regenerating an adjacent blank area; seedlings older than three years were not found, and this would indicate that regeneration commenced when the mother trees were slightly over thirty years old. In the cases quoted it is probable that regeneration was effected entirely from the trees round the edges of the plantations. On the other hand, numerous instances have been observed where trees in dense crops well above the minimum age of seed production, and in localities of good quality, have failed to bear any cones, even in good seed-years. It may be noted that male flowers are produced at an earlier age than female flowers.

Crown development has an important influence on seed production, trees with full rounded or umbrella-shaped crowns bearing a much larger number of cones than those with conical crowns; in good seed-years, nearly every tree of the former type is heavily laden with cones. The selection of seed-bearers from among trees with full crowns is therefore a matter of great importance.

As regards the fertility of seed from trees of different sizes, germination tests carried out at Dehra Dun with seed collected in the Naini Tal and Rawalpindi divisions from 38 trees varying from 1 ft. 11 in. to 10 ft. 8 in. in girth, gave the following results:

1. Seed from 33 trees 1 ft. 11 in. to 5 ft. 6 in. in girth had a fertility varying from 40 to 100 per cent. and averaging 83 per cent.; the Naini Tal seed averaged 93 and the Rawalpindi seed 81 per cent. Seed from only five trees had a germination percentage of less than 75; seed from one tree 1 ft. 11 in. in girth had a fertility of 100 per cent.

2. Seed from five over-mature trees 6 ft. to 10 ft. 8 in. in girth had a fertility varying from 35 to 60 per cent.



FIG. 418. *Pinus longifolia* CONES OF THE THIRD AND FOURTH YEARS X

a - Cone during winter of second year and early part of third year (needles cut short) b - Cone during process of opening, May of third year c - Single cone scale showing pair of seeds d - Seed
e - Old empty cone in fourth year

It is important at times to be able to forecast a good seed-year two years in advance. The majority of the young female cones are found in the upper parts of the tree. With a pair of field-glasses they can be seen distinctly at the apices of the new shoots in March and April. They are, however, clearly visible from below only for three or four weeks or even less, while the new needles are quite short; after this the needles soon become long enough to hide the young cones, so that the time during which it is possible to see them is strictly limited.

The seed of the chir pine falls some little time before the commencement of the rains and germinates not long after falling; while on the ground, therefore, it is not subjected to the attacks of pheasants and other birds to the same extent as the seed of the blue pine or the deodar, which lies throughout the winter. While still in the cone, however, the seed is subject to the attacks of certain birds and animals. Mr. A. E. Osmaston,¹ from observations in British Garhwal, enumerates wood-pigeons, nutcrackers, woodpeckers, and grosbeaks, as well as monkeys and flying squirrels. The large amount of seed consumed by flying squirrels in the case of *Pinus excelsa* has been noted on p. 1022; similar extensive damage is caused in the case of *P. longifolia*, and can be detected from the fact that the cone-scales are bitten off sharp at the base, the central axis of the cone being left. Monkeys tear the cones in shreds to extract the seeds. Mr. Osmaston notes that in Garhwal the seeds are eaten by man, the cones being collected before they open and opened by the action of fire: this is done also in parts of the Punjab.

GERMINATION (Fig. 419, *b-f*). Epigeous. The radicle emerges from the end of the seed and descends, the hypocotyl elongating and raising above ground the cotyledons, the extremities of which are enclosed for a time by the shell of the seed, which eventually falls to the ground, when the cotyledons, 9-13 in number, spread out in a whorl, from the centre of which the young shoot makes its appearance.

THE SEEDLING. The following is a description of the seedling and its development during the first five years:

First year (Fig. 419). *Roots*: primary root long, wiry, flexuose, brown, with a moderate number of fibrous lateral rootlets. Natural seedlings in dry localities frequently have taproots 15 in. in length or more in one year; in rocky ground the taproot is often much twisted in its efforts to penetrate cracks in the rocks. *Hypocotyl* distinct from the root, 0.75-1.8 in. long, cylindrical or fusiform, at first white and green, soon becoming reddish or light brown, glabrous. During the first year the epidermis commences to peel off in longitudinal papery exfoliations, and in luxuriant specimens the hypocotyl is often much thickened by the end of the first season. *Cotyledons* 9-13, whorled, 1.2-2.7 in. long, acicular, incurved, prominently triquetrous, compressed laterally, glaucous green or light green, inner edges minutely and somewhat widely serrulate. Towards the end of the first season the cotyledons sometimes turn yellow or brown, and may even disappear if much bespattered with earth in the rains. *Stem* (above cotyledons) erect, terete, pale green or greenish grey; length by the end of the first season varies greatly from under 0.5 in. in poor specimens to 3 in. or more in vigorous plants. One or more lateral buds sometimes appear at or near the base of the stem above the cotyledons. *Leaves* of the first season all primordial, 0.6-1.7 in. long, some-

¹ Ind. Forester, xlv (1918), p. 462.

times longer in vigorous seedlings, acicular, obscurely triquetrous, pale glaucous green, sharply serrulate, minutely punctate in longitudinal lines of stomata.

Second year (Fig. 421). *Roots*: primary root in vigorous specimens on rich soil often much thickened and not conspicuously elongated; on poorer soil the root may elongate to 2 ft. or more; lateral roots usually few and short in natural seedlings, longer in well-developed nursery plants. *Hypocotyl* still distinct, light brown with greyish brown papery exfoliations, often much thickened in vigorous specimens. *Cotyledons* at beginning of season either present or fallen off; if present, usually turning yellow or brown; by the end of the season the cotyledons have disappeared, but their position is still well marked. *Stem* elongates to as much as 14 in. in vigorous specimens, but as a rule reaches a height of only about 5-8 in. in natural seedlings; in vigorous plants there are frequently side shoots of some length springing from the base of the stem, otherwise buds are generally perceptible at that point. *Leaves*: primordial needles up to 23 in. long, the longest near the apex of the shoot; these needles cover the whole stem down to the top of the hypocotyl unless killed off by the wash of earth. Only in the most vigorous plants do adult needles in clusters of three commence to be formed during the second season; in most seedlings buds only are formed, these giving rise to adult needles in the third season.

Third year. The seedling during the third season (age about 1 year 7 months to 2 years 5 months) is characterized by the appearance of adult needles in clusters of three as well as primordial single needles. In strong uninjured plants only adult needles, up to 8 in. long, are produced towards the apex of the shoot, where also a group of buds, forming next year's terminal shoot and whorl of lateral shoots, forms towards the end of the season; these buds enclose adult needles. In injured or backward specimens primordial needles may occur up to the apex of the shoot, adult needles being usually also present. The size of the seedlings varies greatly, the maximum height ordinarily attained being about 2 ft. by the end of the season. In the lower part of the stem side shoots of some length are often numerous in strong plants, while rosette-like arrested branches are also common. The primordial needles of former seasons in the lower part of the stem wither and hang down or fall off in part.

Fourth year. In the fourth season (age about 2 years 7 months to 3 years 5 months) adult needles are regularly produced, though primordial needles are also formed on all but the most vigorous plants, and particularly if any injury is suffered. By the end of the season a maximum height of 3 ft. 4 in. may be reached, though for natural forest seedlings about 1 ft. 8 in. would be a fair average. The lower part of the stem becomes free of dead needles, and in vigorous plants the first semblance of rough bark commences. Fig. 422 shows natural forest seedlings early in the fourth season.

Fifth year. In the fifth season (age about 3 years 7 months to 4 years 5 months), only adult needles are formed, except when the plant has been injured or retarded by some extraneous influence, when primordial needles are also formed. Vigorous uninjured plants now commence to assume the characteristics of the tree rather than of the seedling. The lower part of the main stem has lost its needles, is forming rough bark, and at the end of the season has a diameter up to 2½ ft. at 8 in. from ground-level; the upper part of the stem is thick and covered with adult needles, and there are strong whorls of stout branches, also covered with similar needles. The maximum height attained by the end of the season is normally about 6 ft., though the average height of natural forest plants is probably under 3 ft.

Fig. 423 shows a vigorous nursery-raised plant 5½ ft. in height in the latter half of the fifth season.

The rate of growth of chir seedlings varies greatly according to the con-

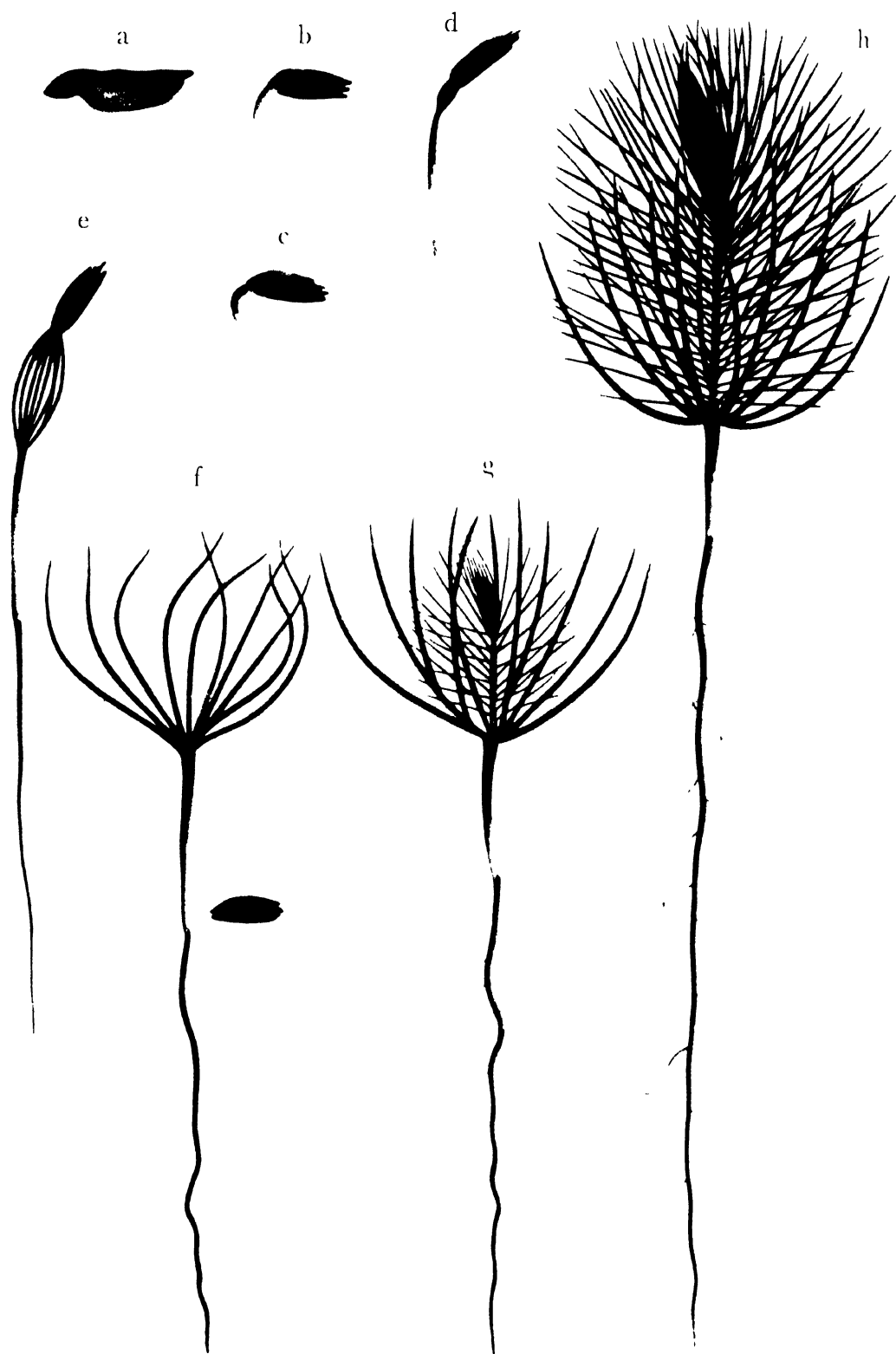


FIG. 419 *Pinus longifolia* SEEDLING $\times \frac{1}{4}$

a Seed b-f Germination stages g, h Development of seedling to end of first season

ditions under which they are grown. Various measurements have shown that given suitable light conditions and ordinary immunity from external dangers, the period required for the seedlings to develop until they begin to put on normal height-growth is under the most favourable conditions five years, while under less favourable conditions it may be as much as twelve to fifteen years ; a fair general average might be taken at eight to ten years, by which time a height of 7 to 9 ft. may be expected to be reached. From measurements of seedlings growing under average conditions it has been estimated that a chir seedling may be expected to attain by the end of the first five seasons a height respectively of (1) 2 in., (2) 6 in., (3) 1 ft., (4) 1 ft. 8 in., (5) 2 ft. 10 in. In a small plantation at Dehra Dun on good arable land, where the height-growth of a plantation thirty years old on similar land showed a mean annual height increment of 2 ft. 7 in., the height of the dominant seedlings at the end of each of the first five seasons was (1) 5 in., (2) 1 ft. 1 in., (3) 2 ft., (4) 3 ft. 4 in., (5) 6 ft. In this case normal height-growth began to be produced in the fifth year. The time at which seedlings began their new season's growth varies considerably ; at Dehra Dun new growth has been observed to commence at various dates from the end of December to the beginning of March, and at higher elevations it begins later. The season's growth ordinarily ceases about October to December.

Chir seedlings are very light-demanding. They persist for a time under slight shade, particularly in fertile soil under broad-leaved species, but even here they become readily suppressed. Measurements of a number of seedlings, suppressed but still growing under a canopy of oak in the Rawalpindi forests, showed that a height of only 3 to 4 ft. was reached in sixteen years, while in an adjoining crop without any overhead cover a mean height of 15 ft. was reached in the same period.

Within the natural habitat of the pine the seedlings are frost-hardy. They are drought-resistant, but on stiff soils in which the root is unable to develop satisfactorily, they may die off in quantity in places exposed to the heat of the sun for any length of time during the day. Young plants cannot endure bad drainage, and where there is excessive moisture in the soil or undergrowth they damp off. Although the seedlings are probably more fire-resistant than those of other Himalayan conifers they suffer greatly from the severe fires which occur within the region of the pine. They are not readily browsed if there are more palatable plants at hand, but in many localities heavy grazing is accountable for a great deal of injury to the young plants, which are browsed down to bush-like form. The effect of fire and grazing on natural reproduction will be considered below.

Among animals, porcupines and rats, where plentiful, do much damage to young chir plants ; the former eat the roots of seedlings and saplings, and the latter gnaw through the taproots of seedlings, especially in nurseries and plantations. Birds do much damage during and shortly after germination, biting off the cotyledons and usually killing the plants. Young seedlings are subjected to various forms of insect damage, perhaps the most serious being that caused by grasshoppers, which bite through the stems.

SILVICULTURAL CHARACTERS. *Pinus longifolia* is a strong light-demander, and where mixed with *P. excelsa* it exhibits more demand for light than the

latter, which is itself a light-demander. On hot, southerly aspects, however, it may require protection from the sun during youth on stiff clayey soil. Hence, although in favourable localities, and especially on cool aspects, a complete removal of the canopy is greatly to the benefit of the young crop, on hot aspects a certain amount of side protection from the sun may be necessary.

The soil requirements of the pine have already been dealt with ; it is one of the least exacting of Himalayan trees, growing on bare rock where few species are capable of existing, but it is intolerant of badly drained ground.

The root-system of the chir is massive, and spreads both downwards and laterally. Although the tree is wind-firm under ordinary conditions, wind-falls are not uncommon on loose soil and on denuded ground. The effect of wind in producing a gnarled and stunted growth is frequently observed, particularly along the edges of woods and on exposed ridges.

In its natural habitat the chir pine is not ordinarily called on to face severe frosts on the airy hill-sides on which it grows ; it has, however, proved itself to be a hardy tree when introduced into frosty localities in India. Thus in the great frost of February 1905, chir trees of all ages planted in the Dehra Dun valley, sometimes in frosty hollows, escaped completely the severe injury suffered by the majority of the broad-leaved species. In some of the frosty valleys of the outer Himalaya the pine, encouraged by fire-protection, can be seen establishing itself at the expense of more frost-tender species.

Growing as it does at comparatively low elevations, the chir is not as a rule exposed to great risk of injury by snow, but when heavy falls of snow do occur within its zone the damage done may be considerable, since the pine is somewhat brittle. Pole crops, particularly those which have not been regularly thinned, suffer most, the poles being snapped in two or bent down, and in some cases uprooted. Snow damage has been observed on various aspects and at different elevations ; it is as a rule more prevalent towards the end of the winter season, when heavy falls of snow in a somewhat wet state are apt to occur.

The chir pine has greater power of resistance to fire than any other important Himalayan conifer, owing to the exceptionally thick bark produced alike on young saplings and on older trees, to the thickened and sometimes almost fleshy taproot developed in the seedling and young sapling stage, and to the power of recovery from injury possessed by plants of various ages. Nevertheless, owing to the fact that the tree is found on hot, dry, inflammable slopes, the actual damage done by fire in chir forests is so great, that in the majority of cases fire is the greatest source of danger to which these forests are exposed. The damage is sometimes aggravated by the custom of chipping out torchwood from the base of the tree, exposing the resinous wood to the direct effect of fire, and in time producing a large charred hollow ; trees so damaged eventually fall, and may be entirely consumed by fire on the ground. Where resin-tapping is in operation the effects of fire are destructive unless the precaution is taken to clear all grass, fallen needles, and debris for some distance round the bases of the tapped trees, otherwise the resin-covered blazes catch fire and great damage may be done to the trees. The effects of fire are aggravated on steep slopes with a heavy growth of grass or bushes ; the fallen needles lodge in the latter, and a fierce conflagration may ensue when they

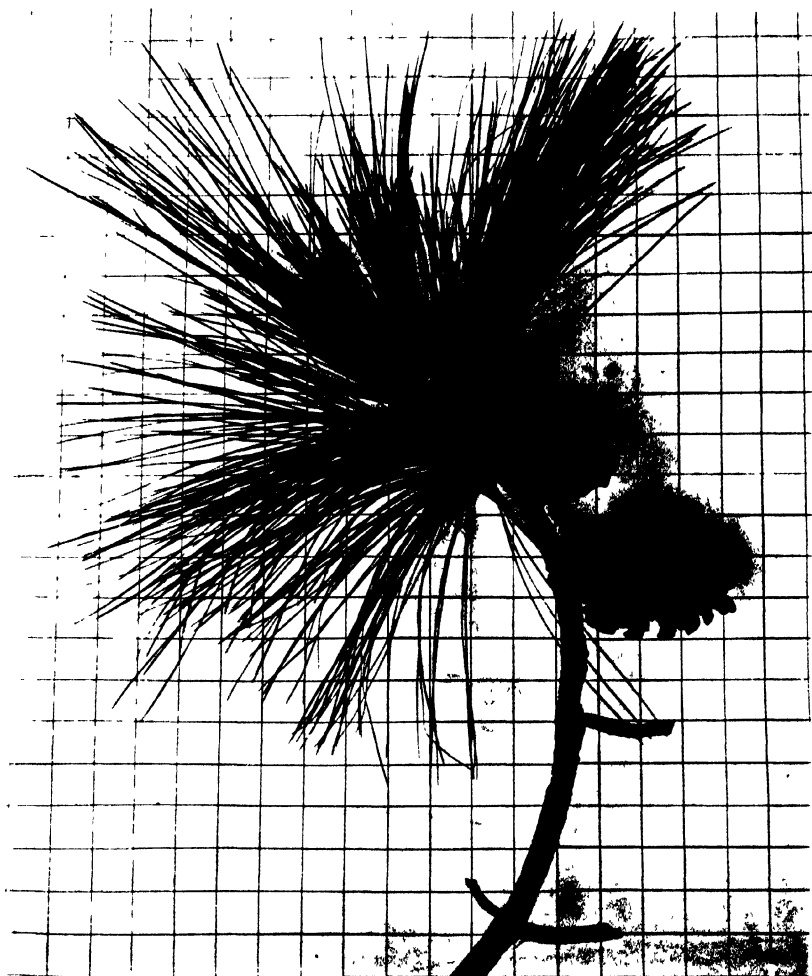


FIG. 420. *Pinus longifolia*, cones of three successive years on one branch, end of October. (1) young cone of current year, about 7 months old. (2) immature cone a year older. (3) old cone which opened in summer of current year. Squares show inches.



FIG. 421. *Pinus longifolia*, two nursery plants, August of second season, age about 13 months. plant on left poorly developed, with no adult needles yet appearing; plant on right vigorous, with adult needles beginning to appear and several side-shoots from the base.



FIG. 422. *Pinus longifolia*, natural seedlings. April of fourth season. age about 2 years 10 months. primordial and adult needles both present.



FIG. 423. *Pinus longifolia*, artificially raised plant, September of fifth season. age about 4 years 3 months, height 5½ ft., needles all of the adult form

catch fire. Uneven-aged crops generally suffer more than even-aged crops, since in the former the fire sometimes ascends into the crowns of the larger trees, producing crown fires which may destroy trees of all sizes ; in the case of even-aged crops large trees are not exposed to this risk to the same extent. The full effect of fire damage is not always apparent for a year or more after the occurrence of a fire, since badly scorched trees may linger for a time and then die ; in the meantime the injured trees become attacked by boring beetles.

In order to mitigate the injurious effects of intense fires in the hot season it is customary in some localities to carry out controlled burning early in the season in areas not under regeneration, thereby reducing the quantity of inflammable material. This burning, which always proceeds downhill, is carried out during the winter or early spring, as a rule shortly after rain. In regenerated areas controlled burning is commenced as soon as the young crop is free from risk of serious damage by fire ; before the initial burning is carried out dead and suppressed stems are removed by an early thinning. The question of fire in its relation to reproduction will be considered under ' natural reproduction '.

Although the damage done by fire to chir pine forests may be very considerable, still its fire-resisting power, as compared with that of other conifers, is strikingly exhibited in some localities in which other species of conifers are encouraged by fire-protection at the expense of the chir. This is seen where the chir zone meets that of the deodar and blue pine. Here the result frequently observed, where fire-protection has been in operation for some time, is that the latter species descend naturally into the chir zone, and a plentiful crop of deodar and blue pine regeneration springs up under the usually open overwood of chir. Fig. 450 shows an open mature crop of chir pine adjoining the deodar zone, under which, as a result of continued fire-protection, a dense young natural crop consisting mainly of deodar, with some blue pine and chir pine, has sprung up. Although this result is due in part to the more shade-bearing character of the deodar, still it is in tracts where fire-protection has been introduced that this form of crop is met with, and the absence of fire is the primary cause of the change of species.

Near the upper limits of the chir, where the pine is mixed with oak (*Quercus incana*), the result of fire-protection as a rule is to favour the latter. At the lower limits of the chir, however, where it is mixed with miscellaneous species of the outer hills, continued fire-protection has been greatly in favour of the pine, which in the Siwalik hills and outer low ranges of the Himalaya has spread, during the last thirty years or so of fire-protection, over a much greater area than it occupied previously.

Within the true chir zone the only destructive climber of serious importance is *Rosa moschata* ; of comparatively small account are *Vitis rugosa*, *V. parvifolia*, and *Clematis Gouriana*. In the Siwalik hills and outer Himalaya the pine, in common with the other trees of the low-level mixed forests, is subjected to damage by such climbers as *Bauhinia Vahlia*, *Spatholobus Roxburghii*, *Cryptolepis Buchanani*, and others.

The commonest fungus found on *Pinus longifolia* is *Peridermium (Aecidium) complanatum*, Barcl. (*P. orientale*, Cooke), which appears on the needles in the form of orange-coloured sacs of spores about April-June ; in this form it

seems to do little if any damage, but when the fungus attacks the branches or the stems of saplings the damage is more serious. In the latter form, known as var. *corticola*, the spores probably enter through wounds, and the fructifications appear about April to June in the form of rather large orange-coloured sacs protruding from the affected portion. The fungus *Hysterium Pinastri*, a most destructive pest in nurseries and young plantations in Europe, was first observed by the late Professor Mayr in 1886 on *Pinus longifolia* in Lurli plantation, Chakrata. This fungus, which is saprophytic as well as parasitic, appears in the form of yellow spots on the needles; these spread until the whole needle turns reddish, and badly affected seedlings die off. The fungus *Trametes Pini*, so destructive to *Pinus excelsa* in some parts of the Himalaya, has been recorded to a limited extent on *P. longifolia*. The spores gain admission through wounds, and the sporophores appear in the form of irregular brackets, usually at the points where branches have been lopped off. Where this fungus is found it is most advisable to prohibit any lopping of the pine.

The branches of the chir pine are sometimes attacked by *Loranthus longiflorus*, particularly at low elevations. This parasite, however, is not so prevalent on the pine as to be a source of any great injury.

Twisted fibre. In certain localities 'twisted fibre' is one of the most striking characteristics of *Pinus longifolia* trees over extensive areas. As the name implies, it denotes that the fibres, instead of running parallel to the axis of the tree, follow a corkscrew-like course at an angle to it. Two distinct forms of twist have been recorded: (1) left-handed twist, in which the fibres run upwards from right to left, and (2) right-handed twist, in which they run from left to right. These two forms possess in some respects entirely different characteristics. Some interesting observations regarding them have been recorded by Messrs. F. Canning and E. A. Smythies;¹ nevertheless the phenomenon of twisted fibre still remains to some extent an obscure one, as its origin has not yet been fully determined. The chief characteristics of left-handed and right-handed twist respectively are as follows:

1. Left-handed twist. The degree of twist varies greatly in intensity from a hardly perceptible inclination to the vertical to one of nearly 90°. Badly twisted trees are often swollen or bulbous at the base, the fibres in the swelling running almost horizontally, and gradually assuming an angle of about 45° when the main stem is reached. In seedlings also a bulbous base is a common preliminary to a twisted-fibred stem. Where the twist is severe it extends into the branches, and the whole tree appears as if it had been subjected to some force which had twisted it into fantastic contortions, the stem and branches being gnarled in every part. Very frequently the twist of the fibres can be observed on the exterior of the tree, the bark-plates following the twist. Sometimes, however, the bark-plates may run vertically up the stem, while the fibres of the wood may be twisted, so that it is not until the tree is felled and barked that the defect becomes apparent. Mr. Smythies notes cases where the tendency to twist diminishes as the tree gets older, so that there is a central core of badly twisted wood surrounded by outer layers of slightly twisted or straight-grained wood. Similarly, poles may be found with

¹ Ind. Forester, xli (1915), pp. 69 and 112.

the lower part of the bole twisted for a few feet above ground-level, and with little or no twist higher up. Mr. Canning mentions that a curve in the stem up to a height of 4 or 5 ft. is often the only outward sign of left-handed twist in young saplings, in which the twisted fibres of the wood are not discernible in the bark; as the tree increases in size this curvature, which appears to be due to injury or to an unfavourable locality, becomes less conspicuous, though it does not necessarily follow that the twist diminishes. Generally speaking, twist is more difficult to detect in young trees than in older ones, where the bark plates are larger and the direction of the fibres is often indicated by faint markings on the plates. These markings do not always run parallel to the direction of the wood fibres, though it is probable that they did so at the time the tissues were formed; this would indicate that the degree of twist in such trees undergoes a gradual change. Left-handed twist is frequently associated with a stunted growth owing to the fact that it is often characteristic of poor shallow soils.

2. Right-handed twist. This form of twist is, according to Mr. Canning, most noticeable in mature trees, particularly in those of good height-growth and with well-formed boles; so far it has not been observed to any great extent on younger trees. As a rule the twist is slight near the base, and gradually becomes more intense higher up the stem; thus almost the only way in which to detect it at some distance is by the contorted form of the branches. The swollen base characteristic of trees with left-handed twist is not found in those with right-handed twist. Again, the latter is not necessarily associated with the stunted form of growth often observed in the case of left-handed twist; it may occur in forests of large well-grown trees. From this it will be seen that the two forms of twist differ in essential particulars, and notably in the fact that left-handed twist is usually more intense at the base of the stem, and often becomes less marked higher up, that is, in the later stages of the life of the tree, whereas in trees with right-handed twist the reverse is the case. Mr. Canning suggests as a reason for right-handed twist being more intense in the upper part of the tree, that during its earlier life, when the height-growth is vigorous, the twist, though present, does not receive full play owing to the rapid upward growth of the stem; when this upward growth diminishes as the tree becomes mature, however, the twist becomes more marked.

Twisted fibre is far more prevalent in the Kumaun hills than in any other locality hitherto examined. Of the two forms of twist the left-handed is, so far as present observations go, far the more widely spread. Right-handed twist is the commoner form in eastern Almora, where in certain localities it is the only form; in all other tracts where twisted fibre has been reported to be prevalent the left-handed form is the invariable rule, and although occasional trees may be found with right-handed twist, these are so rare as to constitute remarkable exceptions. In western Almora left-handed twist is almost universal. It may be mentioned that the trees in eastern Almora are taller and of finer growth than those in western Almora, though this is no doubt due in part to the fact that the population in the former is more scanty and the felling of trees for local requirements has been less extensive.

The effect of twisted fibre on the market value of the trees may be realized

from the fact that trees with anything but the slightest twist are unsuitable for sawing into planks or sleepers, while badly twisted wood cannot even be split into fuel billets ; twisted poles are used to some extent by right-holders. Since considerable areas of forest exist where practically every tree is badly twisted, it can be realized that such forests are useless for the production of either timber or fuel. The case of trees to outward appearance straight-grained, while internally twisted, is perhaps the most serious of all, since additional loss is occasioned in felling and partial conversion before the twist is detected. In the forest administration report of the Kumaun circle for 1913-14 it is mentioned that in selecting sleepers for antiseptic treatment, 17 per cent. were rejected owing to twisted grain. The following instance noted by Mr. Smythies will further serve to show the extent of loss which may be occasioned through twisted fibre :

‘ Three years ago, when there was a big demand for sleepers, a contractor applied for some trees from a block in the valley of the Kosi river, which had never been exploited. Many of the trees in this block were obviously twisted, but many appeared magnificent specimens, with tall straight cylindrical boles of large girth. The writer personally marked the trees, and to give the experiment a fair trial picked out the finest trees available ; every tree taken the contractor himself approved as straight grown. In due course the sleepers obtained were inspected. Undoubtedly 75 per cent. would have been rejected for antiseptic treatment, while not less than 10 per cent. had actually broken across in seasoning ; many of the trees had proved to be twisted inside, with an outer ring of practically straight-grained fibre.’

The above remarks refer mainly to left-handed twists. As regards right-handed twist, Mr. Canning records the following observations :

‘ It is a generally accepted fact in the district that a right-hand twisted tree is not so bad as a left-hand twisted tree. So long as the commercial exploitation of tracts containing these trees had not commenced the right-holder was the only person affected. His usual custom was to fell a tree and use only a small portion from the base of the same, leaving the remainder to rot in the forest. As the twist is least towards the base, it did not affect him much. With commercial exploitation this twist is really more objectionable than the left-hand one, as sawyers fell a tree which on casual examination at the base appears fairly straight, and then having had the trouble of felling it are loth to leave the portion in which the twist is bad. Forest officers in marking such trees are apt to make bad mistakes in classifying them as fit for sawing unless great care is taken, and even with great care must often be in doubt. Until the tree is actually felled and barked, the exact degree of twist in the upper portions cannot be definitely known, and consequently until then the possibility of its being fit for sawing is doubtful. Whether right-hand twisted sawn timber warps in the same manner as that of the left-hand twisted trees is not yet determined. It appears likely that it is not so bad, but the doubt at present precludes its use for railway sleepers. In checking sleepers sawn from such trees when freshly sawn, I have often only been able to see the twist in one or two sleepers out of a batch of sixteen sawn from the same tree. If any sleeper has a wane the twist of the fibre is clear on it, but with four sawn surfaces it is very difficult to detect. The twist is not so great that the timber could not be split up into billets for fuel, but in the tracts where it is found there is no demand for fuel of this nature.’

We may now proceed to discuss the evidence available which will throw any light on the origin of twisted fibre. Right-handed twist has not yet received

sufficient study, and the following remarks should be taken to apply mainly to left-handed twist.

Heredity has been suggested as being responsible for the defect. Mr. Smythies has on two separate occasions raised nursery seedlings from seed collected from trees with intense twist, and without exception the seedlings came up without any sign of twist. Again, in the Almora plantations, although the seed sown must almost certainly have been obtained from trees with twisted fibre, there being no straight-grained trees in the neighbourhood, the trees in the young crop are remarkably free from twist ; they have been systematically protected from fire, grazing, and other injury, and the soil has improved owing to this protection. Mr. Canning mentions an area in eastern Almora where mother trees with right-handed twist have produced offspring with left-handed twist ; here the conditions were unfavourable to the seedlings. In 1912 seedlings were raised in Dehra Dun from seed collected from badly twisted trees in Kumaun and planted on fertile arable land. By 1919 they had developed into saplings 8 to 12 ft. high. There were four survivors, and of these three showed pronounced twist from right to left, while the fourth was very nearly straight-grained. So far as evidence goes, therefore, the question of heredity has not been satisfactorily solved, and before a solution is reached the results of experiments of a more exhaustive nature will have to be awaited ; such experiments have already been started in Kumaun.

Geological formation is almost certainly a contributory factor in the production of twisted fibre. Generally speaking, stratified rocks, such as tertiary sandstones, are remarkably free from twist, while laminated metamorphic rocks, and particularly mica schist, are markedly productive of twisted fibre, though there are notable exceptions. On the tertiary Siwalik sandstones flanking the Himalayan formations in the Naini Tal district, twisted fibre is almost unknown, and this is also true of the Siwalik hills farther west, where the pine grows chiefly on sandstone and conglomerate. Even in the poorest portions of the Rawalpindi district, on bare sandstone rock, the trees, though excessively stunted and gnarled, do not show any marked tendency to twist. On quartzite formations, which do not exhibit a laminated structure, the pine appears to be generally free from twist, even though growing on almost bare rock. On the dolomites of the Naini Tal hills twist is rare. In the Khanpur range of Hazara chir trees growing on hard limestone are usually stunted, but they do not exhibit any marked tendency to twist. The granites and granitic gneiss of eastern Almora are fairly free from twist ; on the other hand, Mr. Smythies mentions that in the Siahdevi block near Almora, on granite, the chir trees show intense twist. The mica schists round Almora are the true home of twisted fibre. In the Kangra valley twisted fibre is fairly common on gneiss and mica schist, the trees being at the same time stunted and misshapen where the soil is shallow ; the areas in question are often in exposed situations, and are subject to grazing. Trees with twisted fibre have been observed on mica schist in the Beas valley in Mandi state at an elevation of 3,200 ft., while trees growing on quartzite in the neighbouring Tirthan valley are not twisted. Some good examples of the effect of mica schist may be seen in the Siran forests of Hazara. The prevailing rock is gneiss, which decomposes into a soft free sandy soil, and on this the chir attains large dimensions and is

free from twist. Occasional twisted-fibred trees occur singly or in small groups, and these are invariably found in places where the gneiss becomes schistose or gives place to mica schist. The occurrence of mica schist, however, does not necessarily result in twisted fibre, as in many parts of the Siran forests there is no sign of twist on this formation. This seems to imply that the properties in the rock which provide the stimulus necessary to induce twisted fibre in the pine are not always present ; what these properties are is not known, though possibly they may include the degree of lamination and the extent or direction of folding. The general prevalence of twisted fibre on mica schist would seem to indicate that under certain conditions the laminated structure and folding of schistose rocks, in causing a gnarling or twisting of the roots, induces a twist in the stem. This might explain the fact that both twisted and straight trees are sometimes found mixed on the same area ; in such cases it is possible that those trees whose roots have to struggle through folded laminations may acquire a twist, while those growing in clefts and pockets in the rock, where the roots have freer play, may tend to grow straight. There are, however, puzzling exceptions which indicate that twisted fibre is not necessarily caused by geological formation alone, and may possibly be the result of a combination of external stimuli. In the Kumaun hills Mr. Smythies has observed that twisted fibre is generally more prevalent on southern and western aspects than on northern and eastern aspects, though there are exceptions, while the intensity of twist almost invariably increases in proximity to villages ; altitude has apparently little to do with its prevalence except in so far that villages are commoner at the lower altitudes than elsewhere.

Climate and wind probably have little or no direct effect, otherwise it would be impossible to explain the fact that straight and twisted trees grow side by side on the same area.

Regarding other probable factors, the following conclusions recorded by Mr. Smythies go far towards solving the question of the origin of twisted fibre :

'Soil and aspect, although possibly not primary causes, are undoubtedly predisposing factors causing twisted fibre. That is to say, forests which under certain treatment might grow up straight grained on favourable soil and aspects, with the same treatment might grow up twisted on unfavourable soils and aspects.

'Fire. A note of Mr. Canning's in the Kumaon Circle Annual Report, 1913-14, is very much to the point : " If burnt over, one year old seedlings are generally killed outright, and older ones die back to near the ground-level, and send out a new shoot, developing a swollen carrotty base. The fibres of the wood in the centre of these swollen (bulbous) bases is always twisted. This twist appears to be generally continued in the upper parts of such young plants, although it is less marked. The dying back of seedlings, whether occasioned by fire or otherwise, appears likely to be one of the causes of twisted fibre in this Circle, but it does not explain the local distribution of this defect." The writer corroborates every word of this note. There is further evidence to bear on this point. In some private estates (at Kausani) there were originally some very fine chir forests in which possibly 30 per cent. of the trees showed twisted fibre. These forests have been burnt annually for years past, despite which a thick crop of young chir plants has come up. But in this young crop the proportion of twist is 100 per cent. This establishes the fact that fire is

a primary cause. Fire, however, is not the only primary cause. If it was, the regeneration in all our fire-protected forests should be coming up straight-grained, whereas in the neighbourhood of villages and where grazing is heavy, a certain portion is still coming up twisted. Cattle in these hills are frequently only taken a short way from the villages, and as we get out of the range of the cattle the regeneration loses its tendency to twist. Here then is another primary cause established.

'To put the matter in a nutshell, the primary causes may be included in the expression, "Damage during youth". In the writer's opinion, a primary cause combined with predisposing factors, in other words, *Damage during youth in unfavourable localities*, is the fundamental reason of twisted fibre in the chir forests of Kumaon. It is undoubtedly a fact that twisted fibre is acquired at a very young stage of development, since damage to an old tree or pole does not produce twist, nor is it inherent in the seed. This combination theory at least helps to explain the local distribution of this defect to a considerable extent. It should also be noted that excessive or repeated damage during the seedling stage alone, even on good localities, is sufficient to cause twist, and also plants growing on pure rock or exceptionally impoverished soil, even if they had not been damaged, are liable to twist.'

The conclusions arrived at so far indicate the lines which should be followed with a view to ameliorating the condition of things in tracts where twisted fibre is prevalent. These are the protection of all regeneration areas from fire, grazing, lopping, removal of litter, and any influence which would tend to damage the young crop or impoverish the soil. In addition, the removal of twisted stems in subsequent thinnings, as far as is feasible, should tend to improve the quality of the crop; in the case of saplings and young poles this will not always be easy owing to the difficulty often experienced in detecting the defect from the outside.

Although the complete eradication of the defect in tracts where it is prevalent may not be possible, the steps indicated should at all events go far towards diminishing its extent and improving the value of the forests; the case of the Almora plantations, already cited, furnishes sufficient proof of the value of protective measures in this respect.

NATURAL REPRODUCTION. The chir pine sheds its seed for the most part from April or May to July. Under natural conditions the seed does not lie ungerminated for any length of time if rain falls in sufficient quantity, but may begin to germinate within ten days of falling; otherwise if the weather is dry the seed lies until there has been a sufficient fall of rain. As a general rule germination commences at the beginning of the monsoon or after the early showers preceding it, if these bring sufficient rain. The readiness with which the seed germinates even under a moderately dense canopy indicates that temperature conditions are suitable for germination in the shade of the pine forests; under conditions of insufficient light, however, the resulting seedlings rapidly die off.

There are several factors which have a favourable or adverse influence on natural reproduction, and it will be convenient to consider them separately under the heads of (1) nature of seed-bearers, (2) light, (3) drought, (4) aspect, (5) topography and soil, (6) soil-covering and undergrowth, (7) fire, (8) grazing and grass-cutting.

1. *Seed-bearers.* It has already been noted that trees still in the vigour of their height-growth and possessing conical crowns with definite leaders

produce good fertile seed and are capable of affording natural reproduction to a greater or less extent ; as a general rule, however, seed in quantity sufficient to effect complete regeneration, after allowing for casualties, is not produced until the trees have acquired the rounded or umbrella-shaped crown characteristic of approaching maturity. Trees of the latter type, therefore, should be selected as seed-bearers in regeneration fellings. Neglect of this principle has in some cases led to almost complete failure in the regeneration of compartments ; examples of this are to be seen in some parts of the Ranikhet forests, where a former working plan prescribed the cutting out of mature trees in seeding fellings and the retention of medium-sized trees as seed-bearers, with the result that considerable areas have failed to restock themselves, although the conditions for regeneration are otherwise favourable. Requirements as regards seed-bearers are now better understood, and such mistakes are no longer made in the forests in question.

2. *Light.* The chir pine is a strong light-demander in all stages of its life, and under favourable conditions the more light admitted the more successful and complete will be the regeneration. The effect of light is clearly shown in Figs. 413 and 431. In the former natural reproduction has appeared in quantity in an open gap on the left, whereas it has failed to appear under a moderate overwood at the top of the slope on the right ; in the latter the mature crop on the upper part of the slope, although fairly open, is not open enough to secure regeneration, whereas the dense young natural crop below it is the result of the free admission of light by the drastic opening of the canopy, amounting in part to an entire clearance of the overwood.

It may be said that under ordinary favourable conditions five to eight good seed-bearers per acre are ample for effecting complete regeneration, and that a greater number are not only unnecessary, but may even be detrimental to the establishment of a healthy young crop. This statement, however, should not be taken to apply universally, for on hot slopes where the soil is stiff and the seedlings are liable to suffer from insolation, protective shade is essential, and the demand for such protection may outweigh the demand for light. There are instances in the Rawalpindi forests, where the slopes are hot and the soil contains a large proportion of clay, of good regeneration establishing itself under an almost complete canopy. Where protection against drought is necessary, therefore, the number of seed-bearers per acre may have to be increased very considerably ; again, on southerly aspects a larger number of seed-bearers are required as a rule than on northerly aspects. Observations further tend to show that in crops of poor quality the spacing of seed-bearers can be a good deal closer than in crops of good quality, the main reason being that the trees are larger and the crowns are broader and denser in the latter than in the former. Fig. 424 shows natural reproduction establishing itself on a hot south-westerly slope in the Rawalpindi forests under cover of an overwood which in a cooler and shadier situation would be dense enough to prevent its establishment ; under these conditions the crop does not regenerate in large even-aged masses, but tends to form groups differing in age. Exceptional cases, however, occur in which reproduction will spring up even on cool aspects under a fairly complete canopy. It is noteworthy that chir pine regeneration, in common with that of other conifers, persists under the shade



FIG. 424. Natural reproduction of *Pinus longifolia* establishing itself under moderate shade on a hot south-westerly aspect, Rawalpindi - Punjab.



FIG. 425. *Pinus longifolia* forest not fire-protected, and characterized by an absence of natural reproduction, Jaunsar, United Provinces.



FIG. 426 Natural reproduction of *Pinus longifolia* established on an area always open to fire and grazing, owing to favourable conditions afforded by a loose porous soil on a gentle slope, Kumaun hills.

of oak for a longer time than it does under equally dense shade of its own kind ; the reason of this is possibly that the soil under an oak crop is ordinarily richer and moister than that under a pine crop, and the young pine retains its vitality for a longer time. Examples of the direct influence of light may be seen in the case of mixed forests of chir and oak where the latter is lopped or browsed ; here pine regeneration usually tends to spread in the gaps created by the mutilation of the oak.

3. *Drought.* In certain localities the mortality among *Pinus longifolia* seedlings owing to insolation is so excessive that regeneration may be entirely prevented ; in some cases even germination fails. This is particularly the case on stiff bare clayey soil, or on shallow soil overlying limestone, on hot southerly aspects. The failure of regeneration on hot slopes where the soil is stiff and clayey is well exemplified in many parts of the Rawalpindi forests, where the scarcity of grass and undergrowth on some of the hotter slopes aggravates the ill effects of insolation ; in such places it has been found that if the canopy is heavily opened out complete failure of reproduction is the result. In the Khanpur forests of Hazara natural reproduction may similarly fail on hot aspects where there is only a shallow soil overlying limestone. The best measures for aiding reproduction in such places are the retention of grass and undergrowth if present, the hoeing of the soil where it is stiff, to enable the roots to penetrate to some depth, the retention of side shade by working in groups or strips, and encouragement of a mixture of broad-leaved species if any can be got to grow.

4. *Aspect.* As a general but by no means universal rule, regeneration is better on northerly than on southerly aspects, except near the upper limits of the pine, this being attributable for the most part to the greater protection against drought afforded to seedlings on the former aspects as compared with the latter ; it is possible also that the beating of the monsoon rain may account in part for the absence of regeneration on some of the bare south-western slopes.

The question of aspect is intimately bound up with questions of soil, insolation, denudation, undergrowth, associate species, light, and other possible factors such as local topography. In the Rawalpindi forests, where conditions for regeneration are on the whole by no means favourable, aspect with its attendant factors appears to play an important part on natural reproduction, and Mr. Jerram¹ has recorded some interesting observations on the subject. He notes that on cleared boundary lines running north and south regeneration is usually absent, while on lines not exposed to the south or south-east it is often excellent. He has also observed that while on southerly aspects regeneration is capable of establishing itself under a fairly dense overwood, it does not necessarily follow that it fails on northerly aspects under similar conditions ; thus he cites an instance in Bagla protected forest, on a north-north-westerly aspect, where good regeneration appeared under a nearly mature overwood in which the crowns of the trees were almost touching, and where the regeneration was excellent in places where they were only 15 yds. apart. This case shows that in dealing with aspect and its attendant factors we are met with exceptions to the ordinary rule, and that generalizations are apt to be misleading.

¹ Revised Working Plan for the Murree Kahuta Forests, 1915.

5. *Topography and soil.* *Pinus longifolia* reproduces well as a rule on well-drained porous soils, such as those containing a fair proportion of sand or fine mica. This is particularly the case on moderate or gentle slopes and rounded spurs; there are many examples of profuse reproduction in such localities in the Naini Tal division (see Fig. 432); cases even occur where reproduction establishes itself well on loose soils in spite of grazing and fire (Fig. 426). On flat places with bad drainage, on stiff clayey soils, and on shallow soil overlying limestone, the pine regenerates badly. This is also the case on bare shaly slopes without any soil-covering, where the seedlings are washed away and regeneration is usually absent; in such places the presence of tussocks of grass is of great assistance in the establishment of seedling growth. On loose friable shale decomposing into a soft soil resembling coarse sand, natural reproduction is often plentiful, as in parts of the Simla hills. Natural reproduction sometimes springs up in great abundance on abandoned cultivation, where the loosening of the soil is favourable to the germination and growth of the seedlings; in such places, however, it fails to appear where the drainage is bad. A marked feature in the case of pine crops on old terraced fields is the tendency of the trees to come up in lines along the tops of the walls separating the fields, whither the seed is washed by rain. The pine readily takes possession of new ground on landslips in the loose tertiary sandstone and conglomerate formations of the Siwalik hills and the flanks of the outer Himalaya.

6. *Soil-covering and undergrowth.* The presence of a thick layer of undecomposed needles, characteristic of chir forests which have been protected from fire and grazing for some years, is inimical to reproduction, and in some cases is responsible for its entire failure. Experiments to demonstrate this have been in progress in Dehra Dun within recent years, and it has been proved that not only does the seed frequently fail to germinate on the top of a thick layer of needles, but has been destroyed, before germination was possible, by ants, which were found to be more plentiful on the needles than on bare ground, while on grass-covered ground there were still fewer ants. If a fire occurs in a chir forest in a good seed-year, before the fall of the seed, the ground at the end of the following rains is usually found to be carpeted with vigorous seedlings, the burnt layer of needles acting as a good germinating bed, and the soil, enriched by the ashes, being in a condition to stimulate the growth of the young plants. On a deep layer of needles, even if germination takes place successfully, the subsequent mortality among the seedlings is often considerable owing to the difficulty experienced by their roots in reaching the mineral soil. In some respects, therefore, the use of fire and the admission of limited grazing may be useful in promoting regeneration. The accumulation of debris from fellings, where plentiful, acts as a serious hindrance to reproduction, and the measures described for the collection and burning of such debris in deodar forests are in certain cases applicable to chir forests.

The presence of a fairly heavy growth of grass on moderate to steep slopes is by no means inimical to chir reproduction, a fact which is proved by the abundance with which the pine regenerates on the grassy hill-sides of the Chakrata division. Fig. 430 shows an example of excellent reproduction which has established itself in such an area. The grass, indeed, is more of

a protection than otherwise, as may be realized by comparing the success of reproduction on even the hottest grass-covered slopes of the Chakrata division with that on those slopes on hot aspects in the Rawalpindi forests which are destitute of soil-covering. On bare slopes with scattered tussocks of grass it is specially noticeable that seedlings are to be found mainly in the shelter of the tussocks, against which the seed is washed before or during germination. A heavy growth of grass on flat ground often denotes bad drainage ; in such places reproduction fails. In a good seed-year burnt grassy areas, like burnt needle-covered areas, become covered with seedlings where there are sufficient seed-bearers.

The effect of shrubby undergrowth on reproduction depends greatly on the locality. If not too dense it is as a rule beneficial, especially on hot or unstable slopes, as it affords protection against the sun and prevents the wash of the surface soil. In grazed areas, also, the presence of undergrowth species which are browsed may be the saving of the less palatable pine seedlings. On hot aspects in the Rawalpindi forests the undergrowth, chiefly *Dodonaea* and *Berberis*, is of the greatest benefit ; Fig. 424 gives an instance of how pine reproduction may establish itself by the aid of the undergrowth in such localities. Among the densest undergrowth species is *Myrsine africana*, which is characteristic of moderate elevations in the same division. Where it is not too dense it appears to be more of an assistance than otherwise, but over considerable areas, particularly in cool situations, it effectually prevents reproduction where it forms thick masses. In some localities, for instance in the Kangra valley, where there is a flourishing undergrowth of *Carissa spinarum*, *Dodonaea viscosa*, and other shrubs, if the opening of the canopy is not quickly followed by pine reproduction, it usually happens that the undergrowth is encouraged by the admission of light to such an extent that reproduction is effectually prevented until special measures are taken for the removal of the undergrowth. The masses of herbaceous and shrubby growth often found in moist situations on cool aspects, where the chir is usually mixed with oak and other broad-leaved species, are always adverse to the natural reproduction of the pine.

7. *Fire*. Under ordinary conditions fire may be regarded as the most destructive agency with which the natural reproduction of the chir pine has to contend. Forests subjected to frequent fires are doomed to eventual extermination, owing to their failure to regenerate themselves, and the introduction of successful fire-protection is followed as a matter of course by good natural reproduction, provided that the canopy is sufficiently open and that such abuses as excessive grazing and grass-cutting are kept in check. The effect on natural reproduction of some years of fire-protection on an area where the ground was previously covered with nothing but grass is strikingly exhibited in Fig. 430, which may be compared with Fig. 425, showing a forest burnt annually, in which not a seedling is to be found ; this is typical of many localities. Further examples of the results of fire-protection may be seen in the spread of the pine in the fire-protected sal and miscellaneous forests of the outer Himalaya.

From this it might be concluded that under no circumstances is it possible to effect natural reproduction except in fire-protected areas. This, however,

is not necessarily the case, for there are, particularly in the Kumaun hills, various instances where reproduction has established itself successfully in areas subjected to annual burning. In such cases, however, the ground is kept so free from grass and undergrowth by grazing, that there is little or nothing to burn, and these areas may almost be considered to be automatically fire-protected; the matter, therefore, resolves itself rather into a question of the conditions under which natural reproduction is possible in conjunction with grazing, and it is therefore in areas with a loose free soil on gentle slopes that we find instances of successful reproduction in spite of grazing and annual burning. It is noteworthy that reproduction will not establish itself under these conditions except in gaps of considerable extent, since it is only in such gaps that the ground is free from an inflammable covering of dead needles. Fig. 426 shows a young crop established in a grazed area which has never been fire-protected; it will be noticed that there is no inflammable undergrowth.

In an article entitled 'Some Aspects of Fire-Protection in Chir Forests',¹ Mr. E. A. Smythies, while commenting on the extraordinarily successful results of fire-protection on chir reproduction in the Naini Tal forest division, quotes examples of the apparent anomaly just mentioned, and makes the further observation that in his experience areas which are brought under fire-protection after years of burning tend to regenerate in great profusion, whereas in those areas which have been successfully fire-protected for many years natural reproduction is becoming more and more difficult to obtain, doubtless owing mainly to the thick accumulation of needles with its adverse physical and chemical effects. The conclusions arrived at by Mr. Smythies are (1) that after years of burning, fire-protection gives an extraordinary and universal stimulus to regeneration; (2) that successful regeneration is possible under the most favourable conditions without fire-protection; (3) that long-continued fire-protection has an adverse effect on regeneration.

In considering the general effect of fire-protection on the natural reproduction of the chir it would be well, however, to avoid the risk of allowing exceptions under specially favourable conditions to obscure the main question, and we may accordingly accept the truth of the general statement that in systematic forest operations the introduction of fire-protection is essential for the successful regeneration of chir pine forests.

8. *Grazing and grass-cutting.* The question of damage done by grazing in *Pinus longifolia* forests is one on which opinions vary considerably owing to the widely different conditions under which local observations have been made. Many examples can be cited where excellent natural reproduction has established itself in spite of cattle-grazing as distinct from goat-browsing, provided the grazing is not excessive and other conditions are favourable. Fig. 426 shows to what extent regeneration is possible on a grazed area where the soil is free and not stiff, the slope is moderate, and there was a crop of palatable grass on the ground when the seedlings were young. Contrast with this the condition of things prevailing in Kangra, where a large proportion of the state forests are subjected to excessive grazing, largely by goats and buffaloes, resulting in an almost entire absence of reproduction. Figs. 427 and

¹ Ind. Forester, xxxvii (1911), p. 54.



FIG. 427. *Pinus longifolia* forest open to excessive grazing, showing a complete absence of natural reproduction, Kangra valley.



FIG. 428 Area closely adjoining that shown in Fig. 427, but closed to grazing, and showing good reproduction of *Pinus longifolia*.

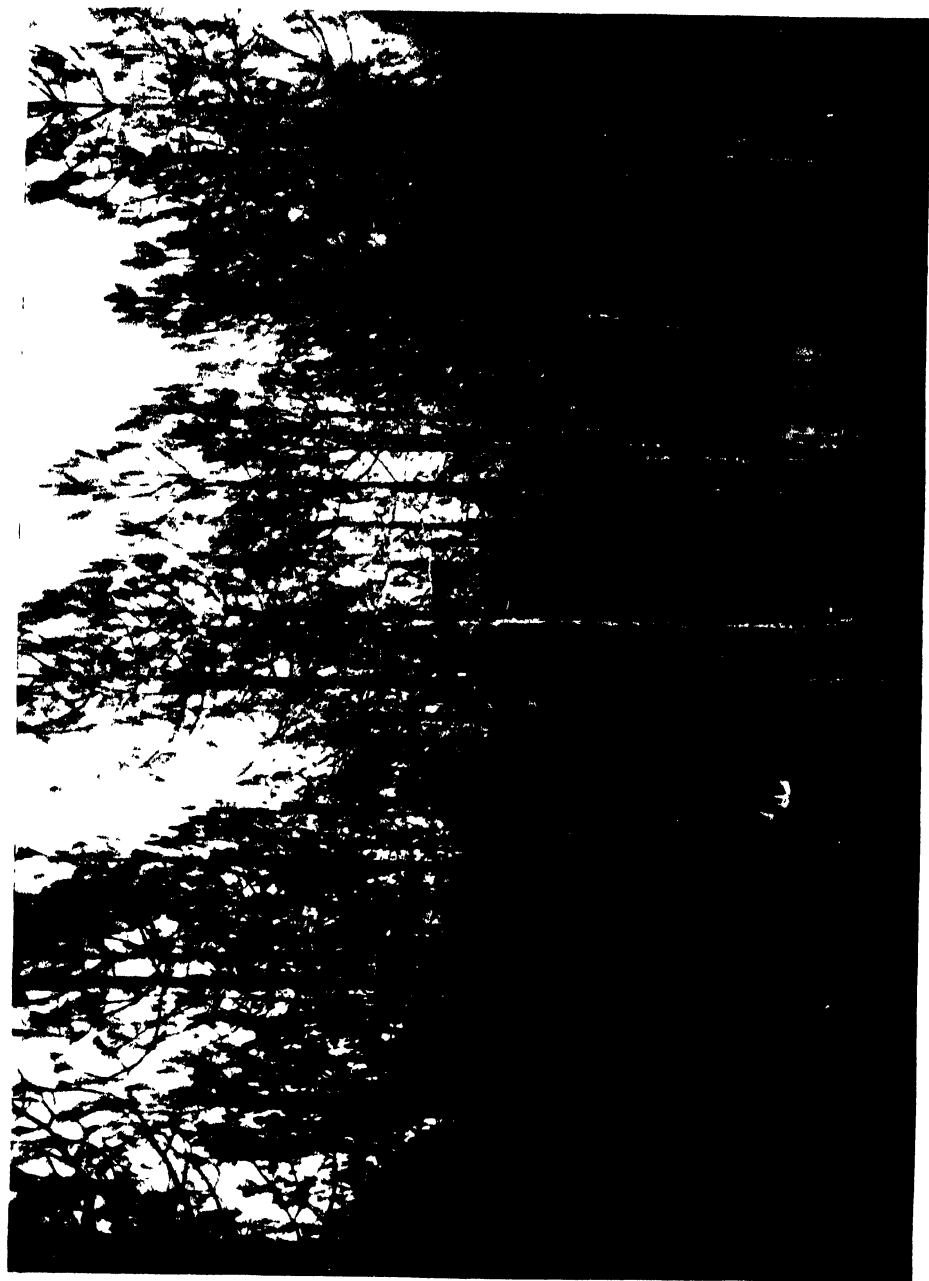


FIG 429 *Pinus longifolia* plantation 19 years old, Baldhoti Almora, mean girth 15.3 in., mean height 27 ft, number of stems per acre 980, solid volume per acre 1 436 cub ft

428 show two closely adjoining areas in the Kangra valley ; the former is open to grazing, and characterized by an entire absence of reproduction, while the latter is closed to grazing, and a promising young crop has established itself. It may be mentioned that grass-cutting in areas under regeneration is always harmful until the seedlings have grown well above the grass.

The chief advantages claimed for grazing in chir forests are (1) that it keeps down dense undergrowth which prevents reproduction ; (2) that owing to the disturbance of the soil and the breaking up of the thick accumulation of needles, germinating seedlings are enabled to send their roots without difficulty down to the mineral soil ; (3) that inflammable grass and undergrowth are kept down and damage by fire is thus lessened. It may be mentioned that these benefits can be secured to some extent by the system of controlled burning. The main disadvantages of grazing are (1) that the trampling of heavy animals, particularly buffaloes, destroys young seedlings, hardens the soil, especially if clayey, preventing free germination, and on steep hill-sides causes erosion and the washing away of seedlings ; (2) that the young pines are browsed down.

On steep hill-sides, especially where the soil is friable, and on stiff soils, the damage done by trampling is aggravated. On difficult slopes, inaccessible to cattle, regeneration is often found to establish itself readily, while it is retarded in the more accessible places. On gentle slopes where the soil is free and sandy, regeneration is sometimes found to establish itself well in spite of grazing.

Where there is an abundance of grass or edible undergrowth the damage done to the chir is considerably lessened. Among favourite plants may be mentioned *Indigofera* spp., *Lespedeza* spp., *Desmodium* spp., *Carissa spinarum*, wild roses and brambles, and to some extent *Berberis* spp. Even goats will avoid *Dodonaea viscosa*, and also as a rule *Myrsine africana*. Where the chir is mixed with oak the former escapes browsing to a much greater extent than the latter, often filling up blanks where the oak and other broad-leaved species are browsed down and remain in the form of bushes ; as regards the species of animal, buffaloes are decidedly harmful, for in addition to the fact that they browse the young pine, their weight aggravates the damage done by trampling, especially on steep hill-sides. Other bovine animals are less harmful, and where grass is plentiful the damage done by them is not great, provided the grazing is moderate : excessive cattle-grazing, however, entirely prevents regeneration. Sheep differ considerably from goats in their tastes, and prefer grass and herbs, provided these are not dried up, to any other form of diet : pine seedlings are not liable to much damage by these animals if any other form of fodder is available in plenty. Goats, although they do not actually prefer chir seedlings to other forms of diet, will eat them readily rather than go any distance in search of other food, and as they attack the buds and young shoots, avoiding the old stiff needles, the damage they do may be considerable. Goat-browsing is the cause of an almost total absence of natural reproduction in many of the protected forests of the Kangra district.

The incidence of grazing must necessarily vary much with local conditions, and particularly with the amount of grass and edible shrub growth present, and general figures, even if available, could have little practical application. Trials in Kangra have shown that very serious damage may be occasioned by

as small an incidence as one goat to 4 acres within a comparatively short period of time.

The grazing question may be summarized by saying that grazing in chir forests not under regeneration is not harmful, but is if anything beneficial, except on unstable hill-sides and, for some years prior to the commencement of regenerative operations, on stiff soils. In areas under regeneration, although special instances can be cited where cattle-grazing in moderation has done little harm, in general grazing and grass-cutting should be strictly prohibited; this applies with special emphasis to grazing by goats and buffaloes. After reproduction has been established and the young crop is out of reach of danger, grazing and grass-cutting would probably be of advantage in most cases, in keeping down inflammable undergrowth and grass, and preparing the way for the first controlled burning. In practice, however serious the damage by grazing may be, questions of rights and privileges must be taken into account, and it may be difficult or impossible to close for regeneration more than a small proportion of the total area under management. This is a strong argument in favour of concentrating regenerative operations, working for even-aged crops, and shortening the regeneration period to the minimum compatible with safety.

ARTIFICIAL REPRODUCTION. General. The chir pine can be raised in the nursery and transplanted with success, provided due care is taken during and after transplanting, and plantations, as opposed to direct sowings, can be made successfully on a small scale in favourable localities; the tree is accordingly often planted in gardens, on roadsides, and in small plantations. For forest operations, however, direct sowing is much to be preferred, not only on the ground of economy, but also as being more successful, since transplanting is attended with great risk of failure in localities such as those in which the pine has ordinarily to be grown on an extensive scale.

The chir has been sown or planted in many localities outside its own habitat, for example in the Nilgiris, in Baluchistan, and even in the Central Provinces, where sowings have so far succeeded well on the Supkhar plateau of the Balaghat district. In the Nilgiris, although the growth of the trees is not good, the plantations, as such, may be considered on the whole to be fairly successful. The pine has been planted in gardens in many parts of the plains of northern India.

Collection of seed. The cones should be collected about the month of March and placed in the sun until they are thoroughly open. They should then be well shaken and beaten until the seed is all extracted. This can be done by placing them in an open box, the bottom of which is composed of wire-netting; the box is then oscillated sharply backwards and forwards by two persons who grasp handles fitted like a pair of shafts at each end of the box, and the seed is thus extracted and falls through the wire bottom of the box on to a sheet placed below. In a good seed-year seed can be collected at a cost of about Rs. 10 per maund of 82½ lb. At Dehra Dun the seed has been found to be very subject to the attacks of ants, and it has been found advantageous to coat it before sowing with red oxide of lead; this protects it effectively in the seed-beds.

Planting. The seed-beds should consist of light unmanured soil, stiff clayey ground being avoided. The soil should be dug up to a depth of 1 ft.

or more and levelled, the beds being well raised. The seed should be sown in March or April in shallow drills 6 in. apart, and lightly covered with fine earth, and the drills should be watered every two or three days in the evening, care being taken not to give too much water. The seedlings will usually be ready for pricking out in July ; this should be done in lines about 9 in. apart, the plants being spaced 6 in. apart in the lines. They may be removed from the nursery and planted out at the beginning of the following rains, or kept another year in the nursery ; in the latter case they should again be pricked out in lines about 1 ft. 3 in. apart, the plants being spaced 1 ft. apart in the lines.

If basket planting is decided on the seedlings may be pricked out into baskets during the first or second rains, according as the intention is to plant out seedlings one year or two years old.

Both in the seed-beds and in the nursery lines careful weeding is necessary, and the ground should be kept loose to prevent caking.

Experiments at Dehra Dun have shown so far that the best time for transplanting is early in November, but in some localities success has been attained by planting early in the rains, about July. Care is necessary to avoid injury to the long taproot, for which reason planting should be done with balls of earth. Basket planting is also successful, but is expensive. A spacing of 5 ft. by 5 ft. will ordinarily be found sufficient.

Direct sowing. Direct sowing may be considered to be the only practicable method of carrying out the artificial regeneration of the pine on a scale extensive enough for forest purposes. Such sowings have been carried out in many localities, chiefly in patches varying in size and spacing or in lines, which on hilly ground should follow the contours. As a rule sowing in small patches or in contour lines has given good results, but on steep, bare slopes where the wash of water and débris is considerable, these have sometimes been found unsatisfactory owing to the scouring of water and the accumulation of débris ; in such places hoed patches at least 5 ft. square are generally more suitable. In all circumstances good drainage is essential, and it is advisable in patch sowings to make the surface of the patches slope slightly downwards to their outer edge or to cut a small drainage channel leading away from them. In selecting patches, advantage should be taken of the shelter afforded by bushes, tussocks of grass, banks, and large stones. The soil in the patches should be worked up to a depth of about 6 in., and the seed should be sown in June, shortly before the commencement of the rains. About three or four seeds per square foot of patch is a rough estimate of requirements. In dry, hot localities care should be taken not to remove grass from around the patches during the first few years, though where very heavy it may be bent back or slightly cleared from over the seedlings where necessary.

Afforestation works. The Baldhoti and Kalimath plantations at Almora, lying at an elevation of 5,000 to 6,250 ft., furnish a good example of successful afforestation with chir pine by means of patch sowings, under conditions by no means favourable. The plantations form two blocks the area of which aggregates about 1,000 acres. Sowings were commenced in 1875 on what was then a barren treeless hill-top with poor, dry shallow micaceous or sandy soil resting on mica schist, and situated for the most part on hot aspects varying from south-west to south-east.

The system of sowing followed was that of small patches spaced at an average distance of about 5 ft. apart, and the precautions noted above were taken as regards their selection and treatment. These barren slopes have in this way been successfully afforested, as may be judged from Fig. 429, which gives a typical view of one of the plantations. Thinnings have been in regular progress for many years, and the material finds a good sale as fuel for the supply of Almora. This, together with the sale of grass, brings in a fair revenue. The following average figures for the nine years 1905-6 to 1913-14 show that even in their present immature condition these plantations yield a very fair surplus :

	Rs. a. p.		
Gross revenue	1	6	0 per acre
Expenditure	0	12	0 "
Surplus	0	10	0 "

The results of measurements which I made in 1911 in fourteen sample plots laid out in crops of different ages in these plantations are given below. The figures show considerable variation in the quality of the crops, the majority of which fall into quality class II (as defined on pp. 1079-80); this is by no means unsatisfactory considering the nature of the locality, and serves to show that the chir pine can be grown successfully on ground where most species would have little chance of surviving.

Pinus longifolia : measurements made in 1911 in sample plots laid out in Baldhoti and Kalimath plantations, Almora.

Serial No.	Age. years.	Mean girth. ft. in.	Mean height. ft.	Number of stems per acre.	Solid volume per acre. cub. ft.	Quality.	Aspect.	Locality.
1	12	0 6.2	9	3,526	490	II-III	S.	Baldhoti C 6
2	12	0 7.6	13	1,947	549	II	E.	"
3	15	0 8.7	15	1,750	614	II	S.	Kalimath C 1
4	15	0 10.5	16	1,220	529	II	SE.	"
5	15	0 10.8	18	1,650	822	II	SE.	"
6	19	0 11.0	17	1,140	646	II	S.	Baldhoti C 4
7	19	0 11.6	20	920	585	II	S.	"
8	19	1 0.6	20	1,160	1,012	II	S.	"
9	19	1 3.3	27	980	1,436	I	S.	"
10	23	1 7.0	31	513	1,184	II	S.	" C 3
11	23	1 7.9	29	560	1,528	II	S.	"
12	36	0 11.2	23	1,220	1,063	III	S.	" C 1
13	36	1 5.3	31	820	1,786	III	S.	"
14	36	2 0.8	47	436	2,386	II	SW.	"

The Almora plantations, as well as contour sowings in lines about 5 to 6 ft. apart, carried out with success in other parts of the Kumaun hills, show that excellent results can be attained in the artificial regeneration of the chir pine at a remarkably low cost. A maund (82½ lb.) of clean seed ordinarily suffices for about 5 to 6½ acres, and costs about Rs. 10 to collect, that is, the cost of collection may be placed at Rs. 1-8-0 to Rs. 2 per acre. Labour for the preparation of the ground and sowing costs about Rs. 2-8-0 to Rs. 3 per acre, so that the total cost works out at about Rs. 4 to Rs. 5 per acre. In the Rawalpindi division recent experiments in hoeing completely—that is, not merely in patches or lines—to a depth of 8 in. cost Rs. 2 per acre, though on

a larger scale with less supervision the cost would probably be somewhat higher. Experimental sowings carried out in 1913 in the same division proved even cheaper. An area of 40 acres, in which fellings had been completed, was burnt, and seed was sown in hoed lines 2 to 3 ft. apart in the beginning of July. An early monsoon prevented the soil-covering from being thoroughly burnt, and partly vitiated the results, though the seed germinated well where the surface and grass had been properly burnt. The cost of burning, collection of seed, hoeing lines, and sowing amounted to only Rs. 1-8-0 per acre.

SILVICULTURAL TREATMENT. The silvicultural treatment of the chir pine can best be considered under two separate heads: (1) silvicultural systems, (2) tending operations.

1. *Silvicultural systems.* The chir pine has hitherto been worked either as uneven-aged forest under some form of the selection system by single trees or groups, or as even-aged forest under regeneration fellings by periods. Owing to the light-demanding character of the pine and its tendency to regenerate where possible in even-aged masses, systems of the selection type have proved unsuitable, and are being discarded in revised working plans in favour of systems of regeneration fellings by periods with the view of producing even-aged crops. It is true that where selection fellings by groups are carried out the silvicultural requirements of the tree are to some extent provided for, but the diffusion of work renders subsequent tending difficult, and the suppression of much of the young stock is almost inevitable; damage by fire is intensified in the uneven-aged crops produced by such a system, while the concentration of fire-protection on areas under regeneration, with controlled burning for protective reasons in other areas, is impossible. Again, resin-tapping operations can be conducted more efficiently and economically when concentrated on definite areas than when scattered widely, as they would be under any form of the selection system. These considerations alone, apart from the question of economy of working under a concentrated system of regeneration and tending, have led in all properly organized chir forests to the abandonment of the selection system in favour of the system of regeneration fellings by periods. The latter system has entirely justified itself in practice, and has been in operation for many years in the forests of Ranikhet and Jaunsar and in the leased forests of Tehri Garhwal.

Under the general scheme of working the whole workable area is divided into two main parts: (1) periodic block I, that is, the portion to be regenerated first within a definite period of years, and (2) the remainder. The former requires complete protection from fire, grazing, and other forms of injury; the latter may, if necessary, be opened to controlled burning and grazing. In the former regeneration fellings are carried out; in the latter subsidiary fellings are made for the utilization of mature trees, the improvement of the existing stock, and where possible the more speedy attainment of the normal forest. In the existing state of the natural chir forests, which are almost without exception in a highly abnormal condition, the allotment of crops to periods, even tentatively, is a somewhat difficult matter. In the Chakrata division, comprising the forests of Jaunsar and the leased forests of Tehri Garhwal, there is an excess of open mature crops; in many of the forests of

Kumaun there is an excess of pole and sapling crops, while in Rawalpindi there is a total absence of woods up to thirty-five years old, such growth being scattered amongst older stock, and a large excess of woods thirty-five to fifty-five years old. Similar abnormality occurs throughout the region of the chir pine, and mature dense woods of considerable extent, such as those found on the continent of Europe, are unknown. Considering the irregular condition of the existing chir pine forests, the introduction of a regular system of management requires the utmost elasticity of working, a question which is gone into at some length in chapter viii of my note on *Pinus longifolia* referred to above.

Considering the value of resin as a minor product, the general scheme of working should, where possible, include provision for resin-tapping operations. As this involves certain complications, the management of resin-tapping is dealt with separately below. Resin-tapping may, for instance, have a decided influence on the formation of felling series, since there is a definite minimum number of trees which can be tapped profitably in one particular locality, for which reason the indefinite multiplication of felling series is impracticable. Resin-tapping, again, tends to increase the rotation if financial considerations are taken into account, since the out-turn of resin increases with the size of the tree until its vitality is impaired through age or otherwise.

In existing working plans the rotations adopted vary from 90 to 160 years, and the regeneration periods from 20 to 35 years, though a period as short as 20 years has been found in the Ranikhet forests to be too short.

The fixing of the regeneration period is a matter of considerable importance. There are obvious advantages in shortening it as far as is practicable. By so doing the area under regeneration at one time, that is, the area where special efforts are necessary to exclude fire and to enforce closure to grazing, is reduced to a minimum, while the hardy light-demanding gregarious pine receives early freedom from overhead cover and is encouraged to form the even-aged masses in which it thrives so well; again, the longer the period the greater the departure from the ideal normal forest. In fixing the period in actual practice, however, there is one consideration which outweighs all others, and that is, that the period must depend on the time required for complete regeneration to be effected and for the young crop to establish itself and become large enough to escape destruction by fire. This period varies with local conditions, but if we start with an unregenerated area it is improbable that it could be fixed at less than about twenty-five years, while in many localities the young crop could not be considered safe under thirty or even thirty-five years, and that only with carefully controlled burning at the end of the period. Where existing advance growth covers the ground the period could doubtless be shortened, and in many localities it would be possible and advisable to remove the overwood over groups of advance growth early in the period; taking the periodic block as a whole, however, it is the youngest regeneration that has to be considered.

In this connexion the use of artificial reproduction by sowings as a means of supplementing natural reproduction has perhaps not received the attention it deserves; such sowings, which can be carried out at a comparatively cheap rate, should assist materially in shortening the regeneration period and facilitating the attainment of the normal forest. Where seed-bearers are absent these



FIG. 430 Uniform seedling felling in fire-protected *Pinus longifolia* forest, resulting in an even-aged young crop Jaunsar



FIG. 431 Uniform regeneration fellings in *Pinus longifolia* forest, Kumaun hills young

sowings could be carried out at the beginning of the period, and elsewhere in places where natural reproduction is not likely to appear in sufficient quantity they might be made fairly early in the period.

The conduct of the regeneration fellings is a matter of great importance, and in the present irregular state of the chir forests, where conditions vary from place to place within narrow limits, anything in the way of rigid prescriptions should be avoided. The number of regeneration fellings should not ordinarily be fixed. In the open condition of most of the existing mature crops preparatory fellings are unnecessary. The seeding fellings are of great importance, and should be carried out as early in the period as is practicable, one or more secondary fellings, the last of which is termed the final felling, being carried out when and where the state of the reproduction requires them, with a view to the ultimate complete removal of the overwood, if possible, by the end of the period.

Under average favourable conditions, the experience of many years now shows fairly clearly that the correct method of carrying out seeding (or first) fellings is somewhat as follows :

1. The larger trees, with sound, well-developed crowns, should be selected as seed-bearers, and in the case of uniform fellings should be spaced at about five to eight trees per acre (say 25 to 30 yds. or more apart) ; only if no trees of this type are available should smaller trees be retained, in which case more trees per acre should be left. On hot aspects it may be advisable to leave considerably more trees per acre, or the fellings may be made in strips or in comparatively small groups.

2. Smaller trees and poles, if isolated or thinly scattered, should be felled to create blanks for regeneration. Well-stocked groups of promising poles should not be felled, but should be left to form part of the future crop.

3. Well-established advance growth of saplings and poles should be completely freed from overhead cover.

4. Opportunity should be taken to remove unsound or badly shaped trees and poles of any size, as well as trees of inferior species whose removal is desirable.

These rules are not intended to apply rigidly, but may be taken as a basis for the framing of rules to suit local conditions.

Generally speaking, it is possible to classify regeneration fellings into three main types—uniform, group, and strip fellings. Uniform fellings involve the more or less even spacing of seed-bearers ; their execution is simple, and wherever conditions are at all favourable they should be adopted in preference to other types of fellings. They have given remarkably good results in the fire-protected forests of the Chakrata division and in the Kumaun hills, especially on areas previously burnt. Fig. 430 shows an admirable example of the result of a uniform seeding felling in the Chakrata division. Fig. 431 shows two adjacent areas in the Kumaun hills, one containing mature forest not yet regenerated, and the other a young regenerated crop obtained by uniform fellings. Fig. 432 shows a regenerated young even-aged crop, resulting from uniform fellings, awaiting the final felling within five years.

Group fellings, as applied to the chir pine, may ordinarily be taken to mean the removal of trees over and around groups of promising advance

growth. The group system as exemplified in Europe would not be applicable in all its details under Indian conditions, as it demands an intimate study of the ground, the felling of a few trees at a time repeated at frequent intervals round each gap, and continuity of action to a degree not attainable in India under present conditions. Where fire-protection is a difficult matter, fellings in groups with a long regeneration period, tending towards uneven-aged reproduction, are sometimes considered to be a safeguard, as the groups of larger saplings and poles might escape destruction where an even-aged young crop would be destroyed. It should be remembered, however, that fires in uneven-aged crops are liable to develop into crown fires, and to do immense damage. On hot aspects natural reproduction springing up in comparatively small gaps has the advantage of side protection from the sun, which is not the case under uniform fellings.

Strip fellings have not yet been tried in chir forests, but they may prove a possible means of regenerating hot slopes where the young crop requires side protection from the sun in its earlier stages; such fellings would proceed against the direction from which the sun does most harm, and would follow a general downhill course, the strips following the contours or being inclined to them with the object of securing side protection from the sun.

Apart from the regeneration fellings, it may be necessary to carry out supplementary operations in order to secure complete reproduction; these will consist usually of burning felling débris and accumulations of needles in the manner described for the deodar (p. 1122), followed by sowing.

2. *Tending operations.* The chir pine normally tends to regenerate in even-aged masses, and where conditions for regeneration are favourable the density is very great and the struggle for existence severe. Fig. 432 gives an idea of the density of young fire-protected sapling crops on loose, sandy soil. Thinnings in such crops require to be commenced in most cases by the time the crop is fifteen years old; the operation comprises mainly the removal of forked or otherwise undesirable stems, and, where there is risk of fire, of dead and suppressed material. The latter work may be costly, but if controlled firing is to be carried out subsequently it is advisable to remove as much inflammable material as possible before commencing the first burning. True cleanings, that is, the removal of inferior species hampering the young crop, are not ordinarily necessary to any great extent in chir forests, except possibly in certain weed-covered areas on cool aspects, or where the pine is making its way through cover of oak and other species.

Existing working plans are somewhat reticent on the subject of thinnings, owing to the fact that dense pole and tree crops are at present the exception rather than the rule. In future years, however, the necessity for thinnings will become more apparent, when the dense sapling crops which have sprung into existence owing to fire-protection and systematic management have reached the pole and tree stage. It is true that a strong light-demander like the chir tends to thin itself out in the struggle for existence, and it is also true that where material from thinnings is unsaleable and the dead wood is left lying on the ground, danger from fire is greatly increased. At the same time, if regular thinnings in congested pole crops are not carried out, there may be considerable loss of increment during the struggle for existence, leading to

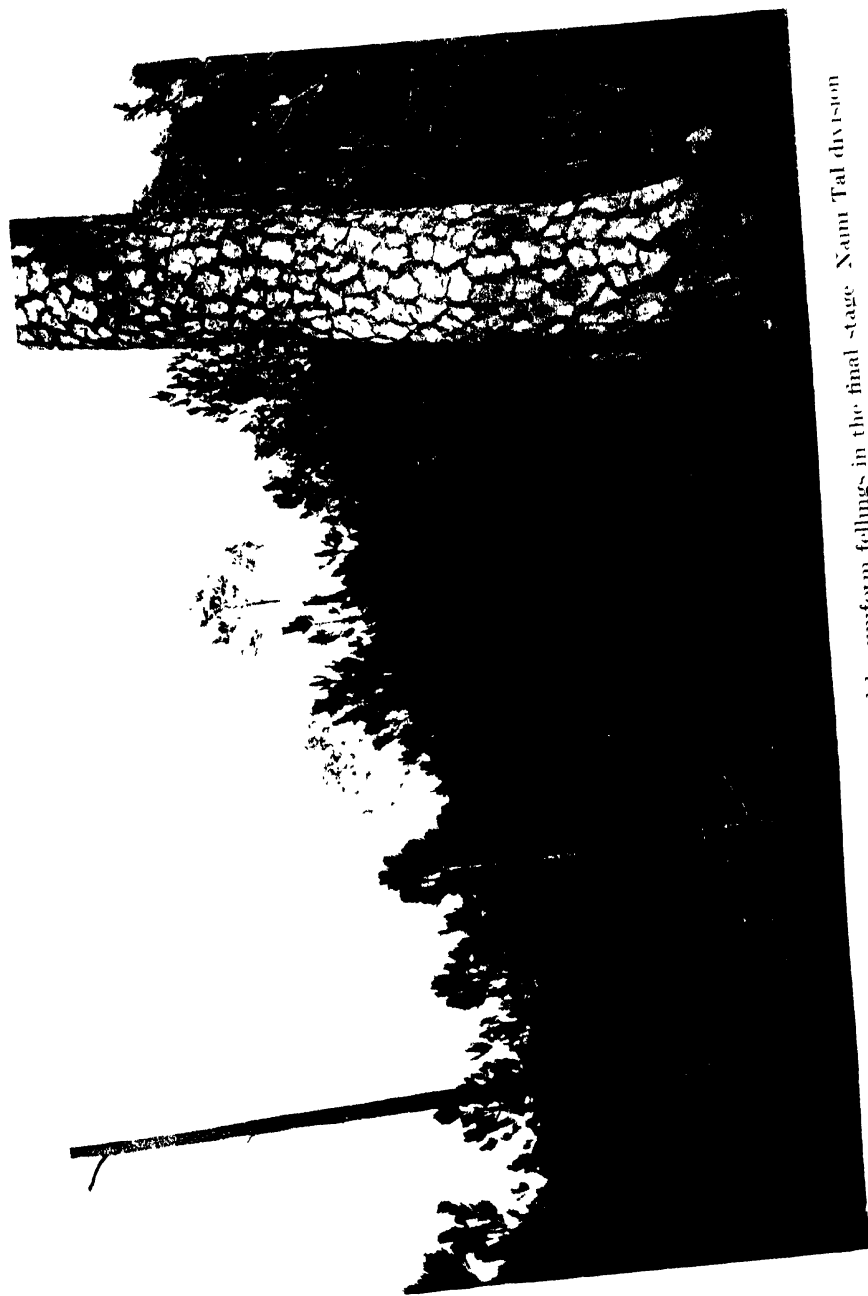
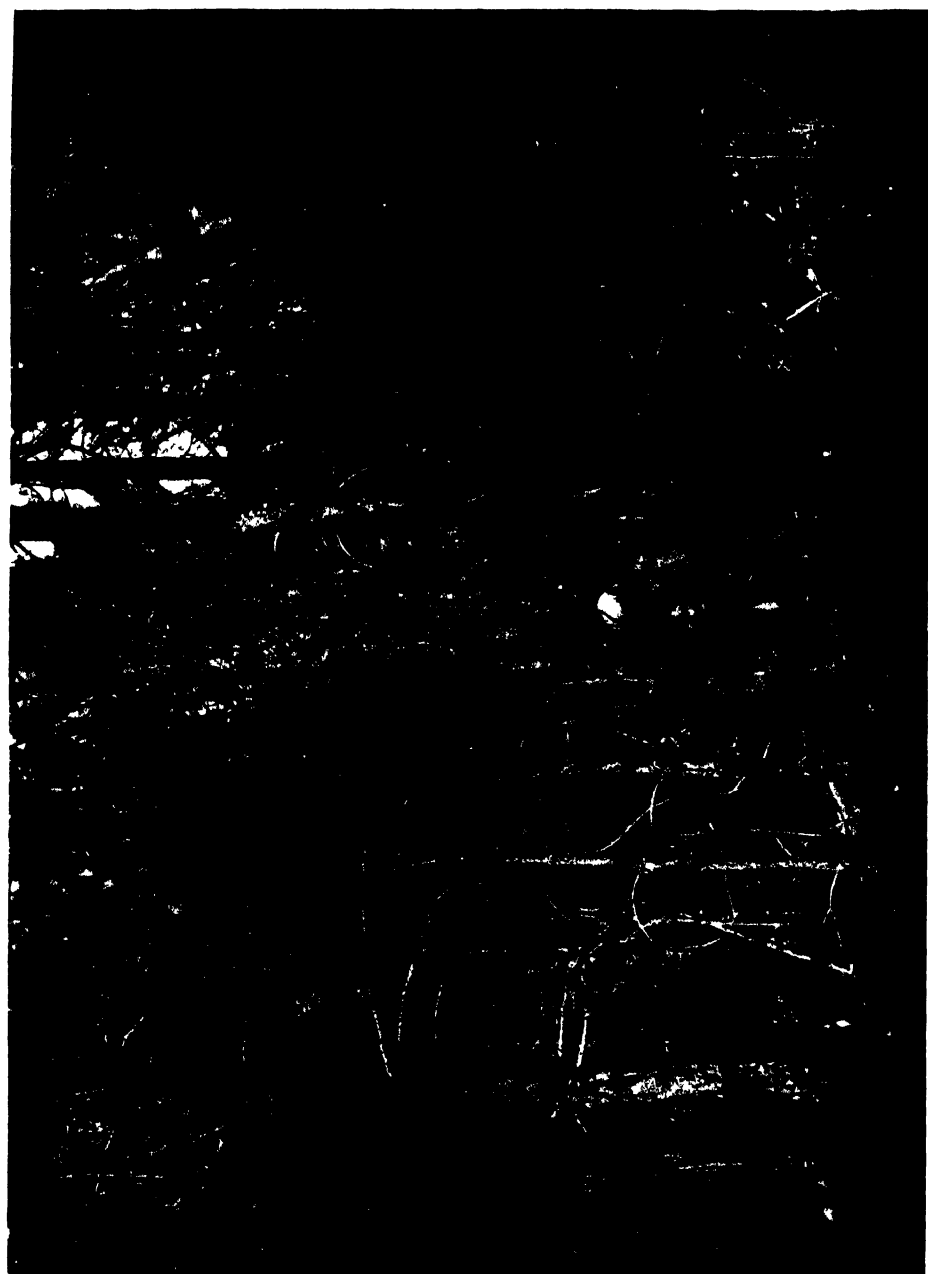


FIG. 432 *Pinus longifolia* forest regenerated by uniform fellings in the final stage seed-bearers being heavily tapped prior to felling.

Nam Tal division



a lengthening of the rotation with its attendant financial loss, while the value of the crops may deteriorate through the survival of undesirable stems ; finally, the risk of fire owing to the accumulation of dead material in the standing crop may be just as great as if this material lay on the ground. The importance of crown development for the production of seed in quantity has already been alluded to, and thinnings are necessary to assist this development.

Where resin-tapping operations are carried out, thinnings in congested crops are required in order to place the trees in a free enough position to be capable of yielding resin in quantity. This principle is well understood in the maritime pine forests in the neighbourhood of Bordeaux, where heavy thinnings are carried out in the interests of resin-tapping.

As already mentioned, it is reckoned that early thinnings, combined where necessary with cleanings, will in most cases be required by the time the young crop has reached an age of fifteen years, if not sooner. Little practical experience has as yet been gained regarding the frequency and intensity with which subsequent thinnings should be carried out, but judging by the results of thinnings made in sample plots within recent years, it appears certain that they should be repeated at least once in ten years. Fig. 433 gives some idea of the density attained by an unthinned pole crop. Fig. 434 shows a portion of the same crop after a thinning. Fig. 435 shows an unthinned crop thirty-two years old, and Fig. 436 a thinned crop seventy-eight years old.

The actual conduct of thinnings in chir crops does not present any special difficulty, involving as it does the general silvicultural principle of removing malformed and otherwise undesirable stems interfering with more promising stems, and giving the necessary growing room to the trees required for the future crop ; efforts should be made during thinnings to cut out stems with twisted fibre wherever possible. The necessity for stimulating crown development for the production of seed indicates the advisability of continuing thinnings after the full height-growth has been reached.

Management of resin-tapping. Under suitable conditions the tapping of resin in chir pine forests, for the manufacture of turpentine and rosin, has shown itself to be a highly profitable industry ; recent years have seen a great development in resin-tapping operations, both in the United Provinces and in the Punjab, and under favourable conditions the revenue derived from resin is larger than that derived from timber and fuel. There is still room for very considerable expansion in the resin industry, and hence in many localities schemes of resin-tapping must influence the management of chir pine forests in no small degree.

The method of tapping followed in India is based on that in vogue in France. An initial blaze about 6 in. long, 4 in. broad, and not more than 1 in. deep is cut near the base of the tree, and the blaze is freshened every six or seven days throughout the summer, until it is about 18 in. long by the end of the year ; if the freshening is carefully done the use of a ladder is thus as a rule unnecessary till the fifth year. The resin collects in a cup fixed at the base of the current year's blaze, and the contents are emptied periodically. A curved channel, in place of the former rectangular channel, is now commonly adopted, as it works easily, does not injure the trees so much, gives a cleaner cut, and so far shows promise of giving a higher out-turn.

There are two classes of tapping, (1) light tapping and (2) heavy tapping, sometimes termed tapping to death. The former consists in making a moderate number of blazes, and is carried out in the case of trees not due to be felled within the next few years. The latter consists in making as many blazes as the tree will hold, and is carried out in the case of trees due to be felled within five years (see Fig. 432), the object being to obtain as much resin as possible before the trees are felled.

In the Naini Tal division light tapping under the present system begins when the trees reach a girth of $3\frac{1}{2}$ ft., and the following number of blazes are cut :

1. Trees over 6 ft. in girth, three blazes.
2. Trees $4\frac{1}{2}$ –6 ft. in girth, two blazes.
3. Trees $3\frac{1}{2}$ – $4\frac{1}{2}$ ft. in girth, one blaze.

The season's tapping commences in March and continues till November, after which the flow of resin practically ceases. In order to promote the free outflow of resin the blazes require to be freshened with an adze at intervals. Experiments carried out by Mr. E. A. Smythies in the Naini Tal division showed that the out-turn increased steadily up to at least ten freshenings per month ; this is borne out by similar experiments made in the Punjab. In Naini Tal, however, it was found that the yield did not increase in proportion to the extra labour required beyond five freshenings per month, and this number, that is, once in about six days, is now universally adopted in that division. As regards labour, in the Naini Tal division the most economical working is found to be attained by an allotment of about 600 trees per man, that is, 100 trees a day per man.

In the case of light tapping, it was until recently always the custom in India to tap for a certain number of years and then to allow a period of rest before recommencing tapping. In Kumaun the rule was to tap for five years and then to give a rest for ten years before recommencing tapping ; this complete period of fifteen years may be termed the tapping cycle. In the Chakrata division a similar procedure was in force till 1914, when a nine years' tapping cycle was introduced, with tapping for three years followed by a rest for six years. The cycle was shortened in order to avoid the use of a ladder, which was found necessary in the fifth year. The highest yield of resin, however, is obtained in the third and fourth years of tapping, and thus by reducing the tapping period to three years considerable loss is involved, which is avoidable considering that a ladder is not required in the fourth season if reasonable care is taken in freshening the blazes.

If a tapping cycle is to be decided on at all, twelve years—that is, four years' tapping and eight years' rest—would be preferable to either nine or fifteen years. The objection to the former has been mentioned, while in the case of the latter it cannot be made to fit in with a suitable scheme of thinnings ; this point is explained below.

In the maritime pine forests of Bordeaux light tapping, once begun, continues without interruption, no rest being given unless a tapped tree shows signs of becoming sickly, when a rest of five years is given ; such cases are rare. In the case of the chir pine, experiments have shown that the tree possesses remarkable vitality even under the strain of heavy tapping, and



FIG 434 *Pinus longifolia*, portion of crop shown in Fig 433, after thinning

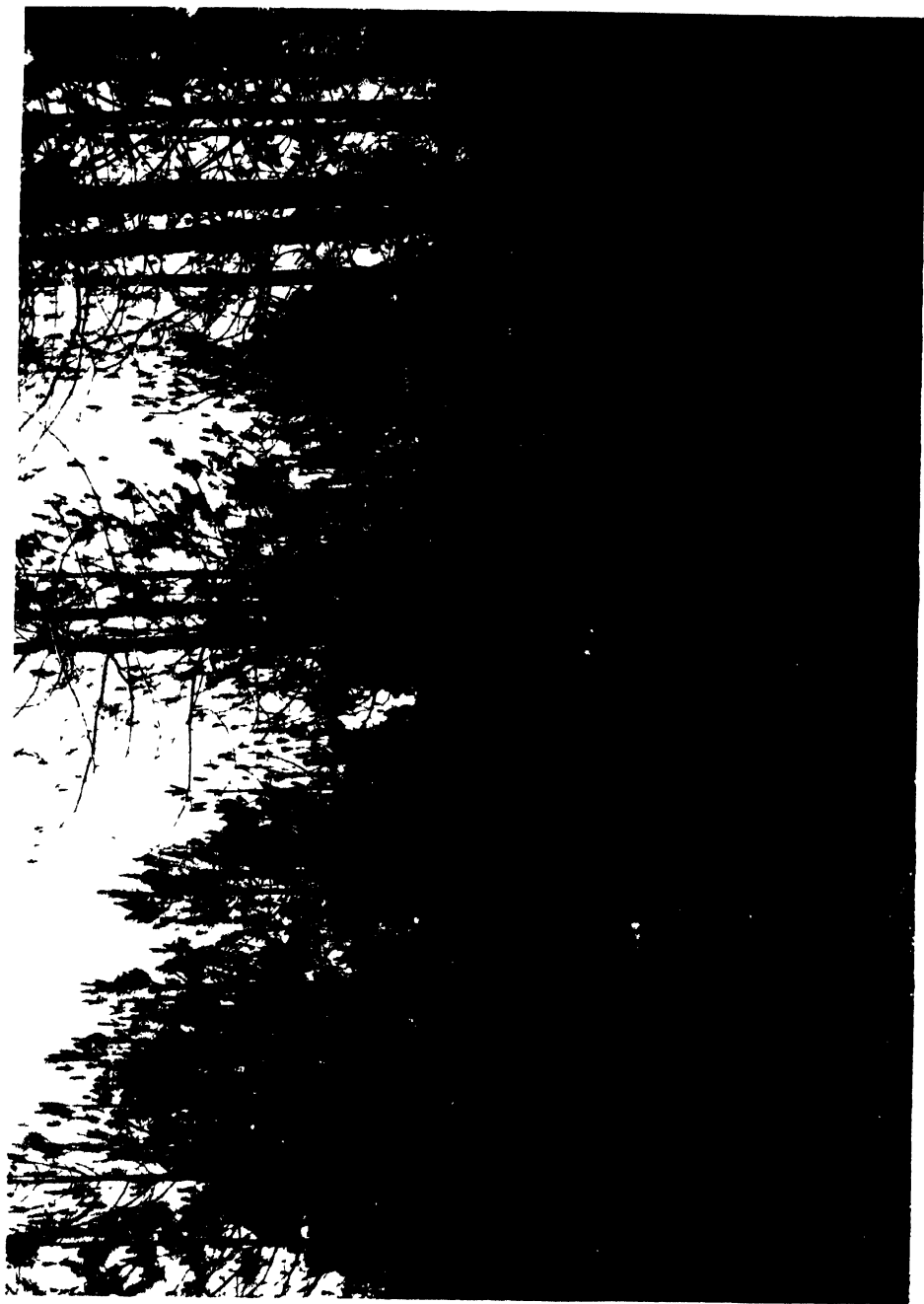


FIG 435 *Pinus longifolia*, natural even-aged unthinned pole crop 32 years old, Kumaun hills

hence rest periods are now being abandoned in favour of the continuous light tapping system of France. Under a scheme of continuous light tapping not only is the out-turn of resin largely increased, but the complication in the general scheme of management, which is inevitable if a tapping cycle is adopted, is avoided.

The main objects of a tapping scheme are to allot for tapping all areas within an economic radius of the distillery, to provide for the continuous working of the distillery up to its maximum capacity by ensuring a sustained equal annual output of crude resin, to allot the tapping areas in such a way as to fit in with the general scheme of working for timber and fuel, and to provide for concentration of tapping operations in the interests of economy.

The chief point to bear in mind is that the tapping of scattered or isolated trees is impracticable; the minimum number of trees which can be profitably tapped on a given restricted area is estimated to be 2,000 to 2,500, and under certain conditions more. It follows, therefore, that heavy tapping is often impracticable by itself, and can be carried out only in conjunction with light tapping. Here the great advantage of continuous light tapping over the employment of a cycle involving a rest period becomes at once apparent, for in the latter case it is necessary to make the intervals between thinnings, regeneration fellings, and subsidiary fellings coincide with the tapping cycle if the maximum amount of heavy tapping is to be secured. In the case of regeneration fellings this is not usually possible without detriment to silvicultural requirements. As regards thinnings, a fifteen years' tapping cycle would be somewhat too long, and since a nine-years' cycle loses one of the years of high out-turn and is therefore unsuitable, we may conclude that a twelve-years' cycle is preferable to either if a tapping cycle is to be adopted at all. As regards subsidiary fellings, these could without detriment follow the tapping cycle.

In view of all these considerations it will be seen that the preparation of an ideal tapping scheme, securing the maximum out-turn with the greatest economy, is practically impossible if a tapping cycle of any kind is employed.

Further experience is necessary before deciding on the most suitable form of continuous light tapping to employ in the case of the chir pine, but a scheme proposed by Mr. Smythies in connexion with his revised working plan for the Naini Tal subdivision is a considerable improvement on previous tapping schemes. The proposed regeneration period is twenty-four years, and fellings are reckoned as commencing half-way through its course owing to the large quantity of advance growth requiring freeing; thus twelve years of the first period remain. The following is the proposed scheme of tapping:

1. Heavy tapping

A. In periodic block I. (1) On trees to be felled in the first five years, as many blazes as possible.

(2) On trees to be felled in the remaining seven years, to commence with

Trees 3-4 ft. in girth to receive one blaze.

Trees 4-5 ft. in girth to receive two blazes.

Trees 5-6 ft. in girth to receive three blazes.

Trees over 6 ft. in girth to receive four blazes.

Additional blazes up to full capacity to be added five years before felling.

B. In other periodic blocks. If marking in these blocks five years in advance of fellings is found practicable, trees to be tapped to full capacity.

2. Light tapping in periodic blocks other than No. 1.

Trees 3 ft. 9 in. to 6 ft. in girth to receive one blaze.

Trees over 6 ft. in girth to receive two blazes.

Continuous tapping to be carried out. Thus, since the first blaze continues for five years, and where the ground is not too steep and a ladder can be used, for six years, the trees will receive during the twelve years' half-period two and four blazes respectively according to size.

Mr. Smythies estimates that in a healthy tree a blaze will heal over completely in twenty-four years or less, and hence under his scheme if the first blaze is commenced on a tree 3 ft. 9 in. in girth, and new blazes are started at intervals of six years, there will never be more than four unhealed blazes on the tree, by which time it will be at least $4\frac{1}{2}$ ft. in girth; this means that there will be one channel to at least 1 ft. in girth, which will never kill a healthy tree.

The yield of crude resin is influenced in a marked degree by certain factors, the chief of which, according to Mr. Smythies, are as follows: ¹

1. *Temperature.* The yield per blaze is greater in hot, dry years than in cool, wet years; it is also greater on southern than on northern slopes. The southern side of the tree produces more resin than the northern side. There is a free outflow of resin in the hot season of the year, whereas practically none is yielded in the winter. Tapping thus commences about the middle of March; the output rises rapidly in April and May, reaching its maximum in July, after which there is a gradual drop, and tapping ceases in November as the yield becomes too small to justify the expense of collection.

2. *Year of tapping.* The yield is smallest in the first year, but the tapping produces wound response, for in the second year it is greater, while in the third year it reaches its maximum. The fourth year produces almost if not quite as much as the third year, while there is a visible decline in the fifth year.

3. *Period of freshening the blazes.* Unless the blazes are freshened the outflow of resin decreases considerably after about the seventh day, and hence labour should be adjusted so that the blazes may be freshened every six or seven days. Actually the yield increases up to about ten freshenings per month (i. e. one every three days), but in practice it has been found that the increase in yield after five freshenings a month is incommensurate with the extra expense of collection.

4. *Vigour of tree.* Vigorous trees produce a higher yield than unhealthy trees or those growing in unfavourable localities. Thus the highest yield is produced within the chir zone proper, that obtained from trees at the upper and lower limits being as a rule smaller, in spite of the fact that in the latter case the trees grow on hot situations.

It will thus be seen that the yield of crude resin may vary greatly according to season, locality, and other conditions. For general estimates an average of 5 maunds (of 82 $\frac{1}{2}$ lb.) per 100 blazes is usually taken. A maund of crude

¹ Ind. Forester, xxxvi (1910), p. 278.

resin yields on an average two-thirds of a maund of rosin and 1.75 gallons of turpentine, of which up to 1.5 gallons are of first quality.

STATISTICAL. 1. *Bark allowance.* The chir pine has an unusually thick bark, the thickness being as much as 3 in. in some cases. For trees 6 ft. in girth and over the average thickness may be taken to be about 2 in. at breast-height, corresponding to over 1 ft. in girth measurement; bark thickness, therefore, has a very appreciable effect where the volume of timber has to be ascertained. The thickness of bark varies greatly with individual trees even of the same girth, so that tables of bark allowance are suitable only for general averages.

The proportion of bark by volume varies considerably. In saplings and small poles it is much greater than in large trees. As a rule the more vigorous the tree the greater the percentage of bark; this percentage falls rapidly after the tree reaches maturity. Measurements carried out in the Rawalpindi forests showed the following percentages of bark in the volume of the whole stem (including bark) down to 6 in. in girth at the small end:

Size of tree.	Percentage of bark.
Poles 1-1½ ft. in girth.	40-56 per cent.
Trees about 3 ft. in girth.	Up to 30 per cent.
Trees 4 ft. to 6 ft. in girth.	10 to 29 per cent. (average about 17 per cent.).

In the Naini Tal division, Mr. E. A. Smythies found that in the case of trees 5 to 7 ft. in girth the proportion by weight of green bark to green fuel averages roughly 10 per cent.

The following may be taken as a rough approximation of the average bark allowance by girth and volume in the case of trees of different girths:

Pinus longifolia: general table of bark allowance.

Girth of tree at breast-height, including bark.	Bark thickness at breast-height. Inches.	Equivalent girth allowance for bark. Inches.	Average percentage of bark by volume. Per cent.
Immediately under 6 in.	0.4	2.5	..
6 in.-11 in.	0.6	3.8	50
1 ft. 0 in.-1 ft. 5 in.	0.8	5.3	46
1 ft. 6 in.-1 ft. 11 in.	1.0	6.3	39
2 ft. 0 in.-2 ft. 5 in.	1.2	7.5	33
2 ft. 6 in.-2 ft. 11 in.	1.4	8.8	28
3 ft. 0 in.-3 ft. 11 in.	1.6	10.6	22
4 ft. 0 in.-4 ft. 11 in.	1.8	11.3	18
5 ft. 0 in.-5 ft. 11 in.	1.9	11.9	16
6 ft. 0 in. and over	2.0	12.6	15

2. *Height-growth and quality classes.* The table on next page, which has been compiled from measurements in 84 Research Institute sample plots in different localities, gives a provisional allotment to quality classes based on height-growth. For the present this allotment must be looked upon as purely tentative and subject to revision after more extensive measurements have been carried out. For ordinary practice it would be sufficient to form three quality classes. There is, however, an inferior type of stunted chir, usually forming rather open crops, where the trees in some cases do not reach a height of more than 25 to 30 ft., and where a maximum height of 50 to 60 ft. is never attained; such crops are hardly of sufficient economic importance to place even in class III, and they have therefore been relegated to a separate class, namely IV.

Pinus longifolia: table of general quality classes.

Age. years.	Limits of height.			
	I quality. ft.	II quality. ft.	III quality. ft.	IV quality. ft.
10	12 and over	7-11	4-6	Under 4
20	28	17-27	10-16	10
30	45	27-44	16-26	16
40	62	37-61	22-36	22
50	78	47-77	28-46	28
60	94	57-93	34-56	34
70	104	67-103	40-66	40
80	110	76-109	46-75	46
90	113	82-112	51-81	51
100	115	85-114	55-84	55
110	116	87-115	58-86	58
120	117	88-116	59-87	59
130	118	89-117	60-88	60
140	119	90-118	60-89	60
150	120	90-119	60-89	60

The table on next page has been compiled from graphs constructed, after discarding abnormalities, by plotting figures obtained from local measurements recorded in working plans and elsewhere. There are evident discrepancies in these figures, due no doubt to their compilation from measurements of single trees which on the whole were probably above the average in quality. For example, the mean height for Rawalpindi is represented as being greater than that for Jaunsar up to an age of 100 years, which is not actually the case, the average quality of the Jaunsar forests being superior to that of Rawalpindi.

3. *Girth measurements.* The following statement has been compiled from girth measurements in 84 Research Institute sample plots in even-aged fully stocked crops :

Pinus longifolia: girth increment in even-aged fully stocked crops.

Age. years.	Mean girth of crop at 4½ ft. (including bark).		
	I quality. ft. in.	II quality. ft. in.	III quality. ft. in.
20	1 4	1 1	0 9
30	2 1	1 8	1 3
40	2 11	2 4	1 9
50	3 8	2 11	2 4
60	4 4	3 6	2 10
70	4 11	4 1	3 4
80	5 6	4 7	3 10
90	6 0	5 0	4 3
100	6 6	5 5	4 7
110	6 11	5 9	4 10
120	7 3	6 0	5 0
130	7 7	6 3	5 2

These girths are probably much below the correct normal average for crops which have been properly tended from youth and regularly thinned ; such are not yet available, and the measurements were actually made in crops the majority of which have been allowed to grow up with a density too high for the best development in girth and volume.

The statement opposite, showing girth statistics, has been compiled from the results of ring-countings recorded in working plans and elsewhere ; for comparative purposes the figures recorded have all been reduced to girth over bark, and the rate of growth in girth has been deduced by constructing increment curves.

Chakrata division. Working plan for the Jaunsar-Bawar forests, 1901. P. H. Gutterbuck (366 stumps).

Working plan for the Naini Tal sub-divisional forests, 1898. N. Hearle (212 stumps).

Kumaun, measurements made in the Binsar forest by C. M. McCrie in 1910 (17 stumps).

Kumaun, measurements made in the Patharia forests by C. M. McCrie in 1911.

Naini Tal division, measurements made by E. A. Smythies in various localities in 1910-11 (500 stumps).

							Age.
ft. in.	ft. in.	ft. in.	ft. in.	Good quality.	Medium quality.	Poor quality.	years.
0 0 ¹	..	..	..	..	..	..	10
1 1	..	..	..	1 6	1 2	0 11	20
1 10	1 5	1 9	2 0	2 0 ¹	1 8	1 4 ¹	30
2 7	2 0	2 6	2 8	2 7	2 2	1 10	40
3 4	2 6	3 2	3 2	3 0 ¹	2 8	2 3	50
3 11	2 11	3 7	3 7	3 6	3 1	2 7 ¹	60
4 6	3 4	4 0	3 11	3 11	3 6	3 0	70
5 0	3 8	4 3 ¹	4 3	4 3 ¹	3 10	3 4 ¹	80
5 6	4 0	4 7	4 6 ¹	4 8	4 2	3 8 ¹	90
5 11	4 4	4 10	4 10	5 0 ¹	4 6	4 0	100
6 4	4 8	5 1	5 1 ¹	5 4 ¹	4 9 ¹	4 3 ¹	110
6 8	5 0	5 4	5 4 ¹	5 8	5 1	4 6 ¹	120
7 0	5 3	5 6 ¹	5 7	5 11	5 4	4 9 ¹	130
7 4	5 6	5 9	5 9	6 1 ¹	5 7	5 0 ¹	140
7 8	5 9	5 11 ¹	5 11	6 4	5 9 ¹	5 3 ¹	150
..	6 0	6 1 ¹	..	6 6 ¹	6 0	5 6 ¹	160
..	6 3	6 3 ¹	..	6 9	6 2 ¹	5 9	170
..	6 6	6 5 ¹	..	6 11 ¹	6 5	5 11	180
..	6 9	6 7	..	7 2	6 7	6 1	190
..	7 0	6 9	..	7 3 ¹	6 8 ¹	6 2 ¹	200
..	7 3	..	..	7 5	6 10	6 4	210
..	7 5	..	..	7 6 ¹	6 11 ¹	6 5 ¹	220
..	7 7	..	..	7 7 ¹	7 0 ¹	6 6 ¹	230
..	7 9	..	..	7 8 ¹	7 1 ¹	6 7 ¹	240
..	..	..	..	7 9 ¹	7 2	6 8	250

been added to the girth excluding bark: this has been corrected by using the allowance of 10 years made for growth of sapling up to breast-height.

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4. *Volume of single trees.* The following table, based on the measurements of all sample trees felled in 84 Research Institute sample plots in even-aged fully stocked crops, gives the average volume of typical trees grown in such crops :

Pinus longifolia : mean volumes of typical trees in even-aged fully stocked crops.

Solid volume in the round (excluding bark in timber and including it in small-wood).

Age. years.	I quality.			II quality.			III quality.		
	Timber down to 24 in. ¹ in girth. cub. ft.	Small- wood 6 to 24 in. in girth. cub. ft.	Total. cub. ft.	Timber. cub. ft.	Small- wood. cub. ft.	Total. cub. ft.	Timber. cub. ft.	Small- wood. cub. ft.	Total. cub. ft.
10	..	1.5	1.5	..	0.6	0.6		0.2	0.2
20	..	4.0	4.0	..	2.0	2.0		0.8	0.8
30	3	5.5	8.5	0.5	4.5	5.0		2.5	2.5
40	9	5.5	14.5	5.5	4	9.5		4.5	4.5
50	19	5.5	24.5	12	4	16	3	4	7.0
60	35	5	40	22	4	26	9	3	12
70	60	4	64	36	3	39	19	3	22
80	82	3	85	46	3	49	30	2	32
90	90	3	93	53	3	56	37	2	39
100	96	2	98	59	2	61	40	2	42
110	99	2	101	61	2	63	42	2	44
120	101	2	103	62	2	64	43	2	45

¹ Minimum girth measured over bark.

The crops in which these measurements were made had grown up without any special tending, and the volumes are considerably less than what might be expected in regularly thinned crops.

In existing working plans there are, on the whole, not many records of volume measurements, and as measurements of single trees growing under a variety of different conditions are apt to give considerable diversity in results, it is not easy to obtain averages of any great utility, particularly as the measurements are not always carried out on the same lines. In the table showing mean volumes of single trees an attempt has been made to arrange the volumes given in working plans and elsewhere as far as possible according to age, after constructing graphs and obtaining average curves. In the case of the Siran range, Hazara, there was such wide diversity in the measurements that an average curve was not easy to determine ; this would indicate that the trees grew under widely different conditions of espacement, quality, &c. In the case of the Kangra and Simla working plans there was little divergence, and the figures given may be considered as representing a fair average of the measurements made.

Subject to these limitations, the table gives as nearly as possible the averages obtained from a compilation of volume figures of single trees from working plans and other sources.

In this table the Rawalpindi and Kulu figures for loss in conversion are based on a large number of measurements, and are on the whole remarkably constant when it is considered that the trees had grown up under a variety of conditions and do not represent the results of careful tending in normal crops. Roughly speaking, these figures show the following results :

d elsewhere.

MEASUREMENTS ARRANGED ACCORDING TO DIAMETER.

Kulu division ; figures prepared by C. G. Trevor in 1918.

Age.	Mean annual increment.	Volume.					
		Local quality I.		Local quality II.		Local quality III.	
		Logs.	Scant- lings.	Logs.	Scant- lings.	Logs.	Scant- lings.
years.	cub. ft.	cub. ft.	cub. ft.	cub. ft.	cub. ft.	cub. ft.	cub. ft.
51	0.09	16	6	12	4	8	2
55	0.10	19	8	14	5	9	2
60	0.13	23	10	16	6	10	3
65	0.17	28	14	19	8	12	4
71	0.19	35	18	22	10	15	6
77	0.23	43	22	26	13	18	8
83	0.26	52	27	32	16	21	10
90	0.28	62	32	38	19	24	12
95	0.32	72	38	45	23	28	14
103	0.35	84	44	52	28	32	17
111	0.38	96	50	60	33	36	20
117	0.41	110	57	69	38	40	23
123	0.44	124	64	80	43	45	26
133	0.46	136	72	90	48	52	30
141	0.48	150	79	100	54	60	35
150	0.50	164	86	110	60	68	40
160	0.51	173	93	120	66	76	44
170	0.53	188	100	130	71	84	48
180	0.54	198	106	140	77	92	52
190	0.55	207	111	149	83	100	56
200	0.56	215	116	158	88	108	60
..	..	222	121	166	93	116	64
..	..	229	126	173	98	122	68
..	..	235	131	179	103	128	72
..	..	240	135	185	108	134	76
..	..	245	139	190	113	139	80
..	..	250	143	195	116	142	84
..	..	255	146	200	120	145	87

[To face p. 1082.]

III QUALITY.

INTERMEDIATE YIELDS.

Number of stems per acre.	Standing crop.		Current.		Total to date.		Total yield to date.		Mean annual increment calculated on total yield to date.	
	Timber.	Total timber and small-wood.	Timber.	Total timber and small-wood.	Timber.	Total timber and small-wood.	Timber.	Total timber and small-wood.	Timber.	Total timber and small-wood.
	cub. ft.	cub. ft.	cub. ft.	cub. ft.	cub. ft.	cub. ft.	cub. ft.	cub. ft.	cub. ft.	cub. ft.
2,000	..	..	..	..	..	..	..	..	..	..
1,500	..	400	..	..	..	..	..	400	..	20
880	..	1,200	..	..	..	..	..	1,200	..	40
670	..	2,200	..	..	..	..	..	2,200	..	55
500	..	3,000	..	130	..	130	..	3,130	..	63
309	1,500	3,500	40	180	40	310	1,540	3,810	26	63
175	2,780	3,700	80	155	120	465	2,900	4,165	41	59
125	3,320	3,850	100	150	220	615	3,540	4,465	44	56
105	3,750	4,000	120	130	340	745	4,090	4,745	45	53
100	3,880	4,100	115	125	455	870	4,335	4,970	43	50
97	4,000	4,200	115	125	570	995	4,570	5,195	42	47
95	4,070	4,250	110	120	680	1,115	4,750	5,365	40	45
	4,080	4,280	110	120	790	1,235	4,870	5,515	37	42

The volume, obtained from quarter-girth-squared measurement, is solid volume in the round.

Size or age of trees.	Loss per cent. in conversion of round timber including bark.
(1) Poles about 40 years old (Rawalpindi)	70-80 per cent.
(2) Trees 50-100 years old (Rawalpindi)	about 57 per cent.
(3) Trees 100-160 years old, good or fair quality (Rawalpindi)	about 54 "
(4) Trees 100-150 years old, poor quality (Rawalpindi)	about 60 "
(5) Large trees 30 in. and over in diam. (Kulu)	about 55 to 60 per cent.

5. *Volume of whole crops.* The yield table facing this page has been compiled from measurements in 84 Research Institute sample plots in even-aged fully stocked crops. These sample plots have not been in existence long enough to provide accurate figures of yields from thinnings, and the figures given have therefore been based on Schwappach's intermediate yield figures for the Scotch pine, the ratio which these bear periodically to the standing crop being applied to the standing crop figures for chir pine. This procedure is likely to give a nearer approximation to what may be expected under normal conditions than an estimate based on the irregular yields furnished by thinnings carried out in sample plots hitherto. The figures showing the number of stems per acre apply to even-aged crops of full density, but as the crops measured were for the most part untended natural crops, in which the density for a given age was greater than what might be expected in regularly tended crops, these figures will almost certainly prove too high in crops where periodic thinnings have had full play for some time.

This yield table, therefore, should be regarded as purely tentative and subject to complete revision when more accurate figures of intermediate yield are available as a result of regular thinnings carried out over a sufficiently long period; such figures will not be available for many years yet.

6. *Form factors.* The table below has been compiled from numerous measurements of typical trees in even-aged fully stocked crops:

Pinus longifolia: form factors of typical trees.

Height. ft.	Form factors.						Remarks.
	I quality. Timber.	Total timber and small- wood.	II quality. Timber.	Total timber and small- wood.	III quality. Timber.	Total timber and small- wood.	
10-20	..	0.58	..	0.60	..	0.60	* Timber ordinarily begins to be produced when the trees are between 41 and 60 ft. in height, and the proportion of timber depends on the girth of the tree. The following are as nearly as possible the timber form factors for different girths:
21-30	..	0.53	..	0.56	..	0.56	
31-40	..	0.49	..	0.53	..	0.50	
41-50	*	0.46	*	0.50	*	0.45	
51-60	*	0.43	*	0.46	*	0.41	
61-70	0.24	0.41	0.24	0.42	0.29	0.39	
71-80	0.26	0.39	0.33	0.40	0.36	0.38	Timber form factors. Girth at breast-height. Height 41-50 feet. Height 51-60 feet.
81-90	0.29	0.38	0.34	0.38	0.37	0.38	
91-100	0.30	0.37	0.35	0.38	..	..	
01-110	0.33	0.37	0.36	0.38	..	..	
11-120	0.34	0.37	0.36	0.38	..	..	
20 and over	0.36	0.37	..	..	..	..	

NOTE.—(1) These form factors are calculated on solid volumes, obtained by quarter-girth-squared measurement, using the formula $f = \frac{v}{s h}$, where f = form factor; v = solid volume; s = sectional area at $4\frac{1}{2}$ ft. from ground-level; h = total height of tree.

(2) Timber is measured without bark, and includes everything in the bole down to a girth (over bark) of 24 inches. Small-wood includes bark, and comprises the top and branches down to a girth of 6 inches.

3. *Pinus Khasya*, Royle. Khasi pine. Vern. *Dingsa*, Khasi hills ; *Tinyu*, Burm.

A large evergreen tree with more or less whorled branches and a crown, oval in young trees, rounded in mature trees. Bark reddish grey, deeply fissured, in moderate-sized to large trees about 1-1.8 in. thick, averaging about 1.5 in. thick. Adult needles 6-10 in. long, shorter on stunted trees, slender, in fascicles of three, the base of the fascicle enclosed in a persistent papery sheath 0.6-1 in. long. There are often two whorls of branches produced in one year, the spring internode being much longer than the summer internode. Wood moderately hard, pale brown to red, very resinous, used in the Khasi hills for building. In Burma it is seldom used except for interior work, as it is not considered durable enough if exposed to the weather. In Burma and in the Khasi hills the resinous wood is much used for torch-wood, the production of which causes considerable injury to the trees. A hole is cut into the bole in order to induce the flow of resin, forming in time a large wound from which pieces of resinous wood are constantly removed until the tree is nearly cut through, when it falls or is blown over.

Pinus Khasya and *P. Merkusii* have a high potential value as producers of resin. Professor Armstrong,¹ who examined samples in 1896, reported that both oils were of the highest quality, that they would probably serve every purpose for which oil of turpentine (French or American) is used, and that they even compared favourably with the French oil. This opinion was confirmed in 1913, after further tests, by Puran Singh,² who found that oil from Assam samples was somewhat inferior to Burma oil, as it contained a greater proportion of high boiling turpenes. Although the forests of *P. Khasya* have been examined to some extent, resin-tapping operations on a commercial scale have not yet been organized, nor has it been ascertained to what extent such operations will prove remunerative ; there is no doubt that many of the tracts of Burma are as yet too inaccessible for profitable tapping.

Under favourable conditions *Pinus Khasya* reaches a height of 100 ft. or more and a girth of 10 ft. and over. Mr. M. H. Ferrars³ measured a tree 10 ft. 4 in. in girth, and another 8 ft. 7 in. in girth and 100 ft. in height, in the hills between the Sittang and Salween rivers in Burma. Round Shillong isolated trees have been measured up to 7½ ft. in girth and 70 ft. in height.

DISTRIBUTION AND HABITAT. Khasi and Naga hills, Manipur, hills of Upper Burma, the Shan States and the hills between the Sittang and Salween rivers.

In the Khasi hills it occurs at elevations of 2,500 to 6,400 ft., thriving best at 4,000-4,500 ft. Except for a comparatively small area under the control of Government the pine forests are much cut up by shifting cultivation, with the result that they consist mainly of young crops. The forests in the neighbourhood of Shillong have been under protection for many years, and now contain crops up to middle age, with girths up to 4 and sometimes 5 ft. The pine forms pure or nearly pure forests (Fig. 437), but it is sometimes associated with various broad-leaved species, particularly along the banks of streams and in damp places, where, if present, it is often represented only by scattered trees ;

¹ Imp. Inst. Tech. Reports, 1903, pp. 167-169.

² For. Bull. No. 24, 1913.

³ Ind. Forester, i (1875), p. 107.



FIG. 436. *Pinus longifolia*, thinned crop 78 years old, mean girth 4 ft 4 in., mean height 102 ft, with 86 stems per acre, Rawalpindi



FIG 437 *Pinus khasya*, pure pole crop, Assam

among the more typical broad-leaved trees are *Rhus semialata*, *Quercus serrata*, *Myrica Nagi*, *Pieris ovalifolia*, *Eurya acuminata*, and *Rhododendron arboreum* (not common).

In Burma there are inconsiderable areas of pine forest on the ridges of the Chindwin drainage and in Myitkyina, aggregating not more than a few square miles. In the Chin hills and Pakokku hill tracts the pine forests are reported to exist at 4,000–8,000 ft. elevation, but their area has not been estimated. The pine is here associated with *Quercus serrata* and other oaks, *Rhododendron arboreum*, *Alnus nepalensis*, and other trees of the drier types of hill forest. In the hills between the Sittang and Salween rivers pine forests occur on most of the ridges from 2,500 or 3,000 ft. upwards, the pine growing either pure or mixed with oaks, chestnuts, and other broad-leaved trees. In the Northern Shan States about 75 square miles of pine forest are reported to exist in the state of Mongtung; elsewhere they are found in more or less scattered patches along ridges in those states and in the hills adjoining them. In the Maing Lon State to the south of Mogôk there are considerable tracts of pine. The largest areas of pine forest, however, are found in the Southern Shan States. A few years ago Mr. Watson estimated the total area occupied by *Pinus Khasya* and *Pinus Merkusii* in these states at 3,000 square miles, distributed as follows:

	Square miles.	
1. Myelat States	300	
2. Lawksawk State	300	
3. Loilong and Mongpai State	300	<i>P. Khasya</i> .
4. Mongpaw and Laihka	150	
5. Mong Kung State	300	
6. Hsatung State	50	<i>P. Merkusii</i> .
7. Mongnai State	100	Both species: probably 70 per cent. <i>P. Merkusii</i> and 30 per cent. <i>P. Khasya</i> .
8. Mawkmai State	100	
9. Mongpan State	600	
10. Kentung (Mongpu and Monghsat)	800	
Total	3,000	

Many of the pine forests of the Shan States and other tracts in Burma have suffered severely from *taungya* cutting (shifting cultivation), working for torch-wood, fire, and wasteful felling generally, and it is probable that their original area has been restricted considerably in consequence. The undergrowth frequently consists of inflammable grass, and when this catches fire large areas of young pine may be destroyed.

Mr. M. H. Ferrars¹ in 1875 gave an interesting account of the pine forests in the hills east of Toungoo, between the Sittang and Salween rivers. He found the pine to occur most gregariously at about 4,500 ft., the forests being always purest on ridges and southerly aspects, and largely mixed with broad-leaved species in ravines and on northerly aspects. In some of the deeper gorges, pine trees of large dimensions were found among other trees. In dense pine forest there was no undergrowth, the soil being covered with a thick layer of humus; bracken fern occurred in clusters, and occasionally cycads were noticeable. The forests were much cut up by *taungya* cultivation, though the less accessible pine forests of the Karenni country were as yet intact. In the areas subject to *taungya* cutting the pine showed a marked tendency to

¹ *loc. cit.*



FIG. 437. *Pinus khasya*, pure pole crop. Assam

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¹ *loc. cit.*

form successive gradations of even-aged crops owing to the profusion with which reproduction springs up on abandoned *taungya* areas.

The geology of the various pine tracts has not yet been studied exhaustively. Round Shillong the pine occurs chiefly on sandstone covered by reddish clay, on which the tree grows well, while small areas of quartzite and shale are met with. In the hills between the Sittang and Salween in Burma the pine forests occur chiefly on granitic rocks and on sandstone. Good drainage appears to be essential; the pine will not grow on swampy ground. At high elevations, on exposed ridges and on shallow soil the trees become stunted.

Detailed climatic statistics are not available for the various regions of this pine. Generally speaking it occurs in sub-temperate, fairly moist regions free from extremes of heat and cold. Frosts may occur during winter, but snow is either unknown or where it does fall the fall is light. The rainfall probably exceeds 70 in. in most of the tracts where the pine is found; in the Khasi hills it exceeds 80 in.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The new shoots appear in February–March. The old needles fall for the most part in April–May, by which time the new ones are full-sized or nearly so. The needles persist for one year and one to three months. The male and female flowers appear on the new shoots in February–March. The male flowers when fully open are 1.5–2 in. in diameter, light brown, with a basal cup of imbricate brown scales which adheres to them when they fall soon after ripening. The female flowers (young cones), 1–3 at the apices of the new shoots, are about 0.5 in. long by 0.35–0.4 in. in diameter, light green, ovoid, the umbo sharply mucronate in the centre. By May next year the cones are nearly full-sized but still green; they ripen from February to April, two years after the first appearance of the female flower. The cones are solitary or in pairs, sometimes in threes, ovoid, 2–3 in. long by 1.5–2 in. in diameter near the base, brown when ripe; scales in spirals of 8 × 5, woody, thickened towards the apex; apophysis depressed pyramidal, with a blunt or mucronate umbo. Seed with wing 0.7–0.9 in. by 0.2–0.3 in. (Fig. 438, *a*), without wing 0.2 in. long; 1,400 to 1,600 seeds, without wings, weigh 1 oz.

Good seed-years are frequent, and the seeds have a high percentage of fertility. Tests carried out at Dehra Dun showed a fertility of 95 per cent. for fresh seed and 65 per cent. for seed kept for one year. In order to obtain seeds for sowing the cones should be collected in February and placed in the sun until they open, when the seeds can be readily shaken out.

GERMINATION (Fig. 438, *b–g*). Epigeous. The radicle emerges from the end of the seed and descends; the hypocotyl elongates, arching somewhat, and the cotyledons are carried above ground. As the cotyledons elongate the shell of the seed remains enclosing their apices for a time, finally falling to the ground, when the cotyledons spread out in a whorl, from the centre of which the young shoot develops.

THE SEEDLING (Fig. 438).

Roots: primary root moderately long, wiry, flexuose; lateral roots few to moderate in number, fibrous. *Hypocotyl* distinct from root, 1–1.7 in. long, green or reddish turning greenish brown. *Cotyledons* 6–8, rarely 9, 1–1.5 in. long, acicular, triquetrous, margins minutely and sparsely serrulate, glaucous

green turning dark green. *Stem* erect, terete, woody. *Leaves* in first season all single primordial, 0.5–1.5 in. long, acicular, margins finely serrulate.

The requirements of the seedling have not been studied in detail. Young plants raised at Dehra Dun reached a height of about 4 in. in the first season ;



FIG. 438. *Pinus Khasya* and *P. Merkusii*. Seedling $\times \frac{1}{2}$.

Pinus Khasya : a, seed ; b–g, germination stages ; h, seedling towards end of first season.

Pinus Merkusii : i, seed ; j–o, germination stages ; p, seedling towards end of first season.

they were found to suffer greatly from the attacks of insects, which killed off numbers of them.

SILVICULTURAL CHARACTERS. The tree is a light-demander, though it will stand slight shade in youth, the amount depending on situation and aspect. Young plants are able to push their way up through a moderate growth of

scrub, particularly on dry, sunny aspects, where they appear to benefit by the shade afforded. In a close crop suppressed trees soon die off, and the crop tends to thin itself out. The tree is wind-firm. Young crops suffer greatly from fire, and are often killed outright; larger trees are fairly well protected from injury by their thick bark. As already mentioned, the trees suffer much injury through being cut into for the production of resinous torch-wood, rendering them liable to be blown down and to become charred by fire.

NATURAL REPRODUCTION. On abandoned cultivation, where the soil has been loosened and exposed, natural reproduction is profuse, and where shifting cultivation is practised dense pure crops of pine spring up; the same frequently happens on burnt areas where the layer of dead needles or the thick matted growth of grass has been burnt. For the establishment of the young crop, however, protection from fire is of great advantage, and may be essential. Reproduction does not appear under a dense canopy, but if the canopy is opened out sufficiently, seedlings establish themselves in quantity wherever soil conditions are suitable.

ARTIFICIAL REPRODUCTION. In certain tracts where shifting cultivation is practised, abandoned fields, as noted below, are regularly sown up broadcast with pine seed, the young pine crops being thereafter protected from fire. Experimental sowings of a similar nature in the Southern Shan States resulted in partial failure owing, it is believed, to too early sowing; it is probable that the best time for broadcast sowing is shortly before the beginning of the monsoon, on ground which has been well broken up. Sowings sometimes fail owing to a dense growth of tall grass, and where this is feared it may be advantageous to sow in lines subsequently kept weeded.

Young plants can be easily raised in the nursery, and bear transplanting well. Seed should be sown in March in raised seed-beds of light porous soil and well watered. Germination commences in a few days to about two weeks. The seedlings should be pricked out in the nursery during the first season, when about 3 in. high, and planted out early in the following rainy season.

In 1916 seed of this pine was sown in ploughed strips near Supkhar in the Balaghat district, Central Provinces, but the results were disappointing in spite of a favourable season. The seed germinated well, but a large number of seedlings were destroyed by caterpillars during the monsoon, and others perished from drought in the dry season. This locality is probably too hot and dry for this pine unless the soil is kept worked up and the seedlings are shaded in the hot season.

SILVICULTURAL TREATMENT. This pine is well adapted for treatment in even-aged crops either by clear felling with artificial or even natural reproduction or by successive regeneration fellings with natural reproduction. In the latter case the general principles applicable to *Pinus longifolia* would no doubt apply to *P. Khasya*.

So far only one working plan for Khasi pine forests has been prepared, namely, the plan dealing with the Shillong pine forests.¹ This plan prescribes a rotation of sixty years, divided into four regeneration periods of fifteen years each. The first periodic block is divided into five annual coupes, so that the block is worked over in three regeneration fellings at intervals of five

¹ Working Plan for the Shillong Pine Forests, E. M. Coventry, 1909.

years. The possibility is entirely by area, and silvicultural considerations have full play. The remaining periodic blocks are worked over by selection and improvement fellings. Provision is made for the conduct of thinnings at intervals, a very necessary prescription in any pine working plan. Where natural reproduction fails, broadcast sowings are prescribed 'in the manner practised by the Khasis', that is, on abandoned *jhums* (shifting cultivation).

In the Khasi hills the *jhuming* system is practised with a fallow interval of seven or eight years. Field crops are grown for two years, and the fields are then sown broadcast with pine. Fires are thereafter excluded. In the more accessible localities when the tree crop is felled, only the pine branches and brushwood are burnt as manure, the young poles finding a ready sale in Shillong. In the less accessible places poles not required for local use are burnt with the branch-wood. Potatoes are the principal field crop near Shillong on the gentler slopes and at the higher elevations. Mr. Ferrars¹ describes as follows the natural regeneration of cleared areas in the hills between the Sittang and Salween rivers in Burma, by the aid of seed-bearers left on the ridges :

'The rotation is twofold. First, there is the set of blocks which are cleared every 15 to 20 years ; these are large and are used for raising the main crops. Secondly, there is a set of smaller blocks or strips which are allowed to lie fallow two or three times as long as the former ; very good forest forms on these, and the land, when cleared, is suitable for growing a series of vegetable crops, &c. The process of regeneration seems to be this. The bare *yah* (temporary clearing) on the slope is seeded for a couple of years by the trees left standing on the ridge ; there being no combustible matter on the ground, the seedlings get a good start and are fireproof afterwards ; fires, however, are carefully and in general successfully excluded by the natives. *Kaing* grass (elephant grass) springs up simultaneously with the young pine, but before it has attained its full development—which it requires a few years to do—the young trees have out-topped it, and subsequently they drive it out of the field in their vicinity, paving the way for a quantity of undershrubs and young pine and leaf trees which then further oppress the grass. Under the struggling leaf tree scrub the pine seedlings, which here seem to thrive in moderate shade, get ahead, and suppress the young leaf trees in their turn. In ten to twenty years the block is full. Under less favourable circumstances the reproduction takes place in belts downwards from the ridge, the successive young generations of pine supplanting and suppressing the grass and scrub.'

The management of this pine for resin-tapping purposes may yet become a matter of importance, and until detailed experience is gained the system followed in the case of *Pinus longifolia* might be taken, *mutatis mutandis*, as applicable (see pp. 1075–1078).

RATE OF GROWTH. Ring-countings by Mr. E. M. Coventry in the Shillong pine forests showed an average of four rings per inch of radius at elevations of 4,500 to 5,500 ft., and five rings at higher elevations, representing mean annual girth increments of 1.57 and 1.26 in. respectively ; allowing 1.5 in. for the thickness of the bark, a girth of 6 ft. over bark would at this rate be attained in about forty to fifty years. The trees measured were in somewhat open situations, and showed a diameter growth probably above the average, which accounts for the adoption in the Shillong pine forests working plan of a rotation of sixty years, corresponding to an estimated girth of 6 ft.

¹ *loc. cit.*, p. 111.

In the hills between the Sittang and Salween rivers, Mr. Ferrars found the growth to vary from four to sixteen rings per inch of radius, giving a mean annual girth increment, without bark, of 0.39 to 1.57 in. Measurements made by Mr. J. Copeland in the Northern Shan States showed that an average tree reached a girth of 6 ft. and a height of 100 ft. in seventy-two years.

4. *Pinus Gerardiana*, Wall. Himalayan edible pine, chilgoza pine. Vern. *Chilghoza*, trans-Indus; *Chūjin*, Chitral; *Mirri*, Chamba; *Ri*, Kunawar. The seed, *Neoza*.

A moderate-sized evergreen, somewhat branchy tree, attaining ordinarily a girth of 6–8 ft. and a height of 50 to 60 ft., and occasionally a girth up to 12 ft. or more and a height up to 80 ft. Branches usually ascending, not whorled, or only obscurely whorled. Leaves in bundles of three, 2–4 in. long, dark green, somewhat stiff, with a basal sheath about 0.5 in. long, which falls by the second year. Bark thin, grey, smooth, with a mottled appearance, exfoliating in irregular thin flakes, which leave shallow depressions. Wood hard, tough, and very resinous, not much used except in regions where other timber is not available. The chief value of the tree lies in its seeds, which are roasted and eaten; they are collected in quantity for export to the plains.

In exposed situations and on poor shallow soil the tree is stunted and gnarled, but under favourable conditions it is fairly tall and straight. Mr. Stebbing¹ records a tree 15 ft. in girth and 70 ft. high in the Shinghar forest in Zhob.

DISTRIBUTION AND HABITAT. Common in Afghanistan and northern Baluchistan. Hariab district of the Kurram valley at 7,000–11,000 ft. Somewhat local in the inner arid valleys of the Himalaya from the Niti pass in Garhwal westward to Chitral and beyond, chiefly between 6,000 and 10,000 ft. This pine is found in the upper parts of the Sutlej, Ravi, and Chenab valleys, not on the Jhelum or in the Kagan valley. It grows gregariously, forming forests of a somewhat open type (Fig. 440), though moderately dense pole crops are also met with (Fig. 441). It is sometimes found associated with deodar, or with *Quercus ilex* and *Fraxinus xanthoxyloides*, or in the trans-Indus with *Pinus excelsa*. It is found only in the dry regions outside the influence of the monsoon, where the rainfall is scanty but there is a heavy winter snowfall, the total precipitation probably amounting to between 15 and 30 in. It endures severe cold in winter; the summer temperature within its habitat probably seldom, if ever, exceeds 100° F. The chilgoza pine makes little demand on the fertility of the soil, and is capable of growing on excessively dry, barren hill-sides with shallow soil, and even on bare rock.

In his account of the chilgoza forests of Zhob and the Takht-i-Suliman, Mr. Stebbing says that in that region the tree thrives between 7,500 and 8,500 ft., but ascends to slightly over 10,000 ft. It occupies a particularly waterless tract, chiefly on limestone, growing at times on what appears to be solid rock. The forest is chiefly uneven aged, and is often fairly dense. In places the chilgoza is associated with *Pinus excelsa*, but the existence of the latter is probably accounted for by the presence of pockets of moisture held up in the rock.

FLOWERING AND FRUITING. The flowers appear in May–June, when

¹ Note on the Chilgoza Forests of Zhob and the Takht-i-Suliman, For. Bull. No. 7, 1906.

pollination takes place. The young female cone increases in size slightly during the first year and rapidly during the second year, becoming full-sized about July ; it ripens about September–October of the year after pollination. The old cones remain on the tree some time after the seed is shed. The mature cone is 5–9 in. long by 3–5 in. in diameter, with very thick, woody scales about 1.5 in. long by 1 in. broad ; the apophysis is triangular, reflexed, ending with a stout umbo which is often tipped with a recurved spine. The seed (Fig. 439, *a*) is 0.8–1 in. long, cylindrical, with a short wing which soon becomes detached and remains on the cone-scale when the seed falls. On an average about 85 seeds weigh 1 oz. The seed is oily, and does not retain its vitality long.

The seed-crop is an important matter from an economic point of view, and hence trees with broad spreading crowns, even if gnarled and stunted, are of more value than well-shaped trees with narrow crowns. Countings by Bhai Sadhu Singh in Baluchistan gave an average of 33 seeds per cone for 40 cones, and the following number of cones per tree :

1. 13 trees under 3 ft. in girth had an average of 28 cones per tree.
2. 18 trees 3 ft. to 4 ft. 11 in. in girth had an average of 51 cones per tree.
3. 17 trees 5 ft. to 6 ft. 11 in. in girth had an average of 80 cones per tree.
4. 12 trees 7 ft. and over in girth had an average of 129 cones per tree.

The largest number of cones on one tree was 400 on a tree 8 ft. 4 in. in girth.

Seeds required for edible purposes are obtained from cones which are still green. The cones are gathered from the trees, heaped up, and burnt in order to cause them to open, after which the seeds are picked out. Much damage is apt to be done to the trees during the collection of the cones ; men ascend the trees and by means of a long pole with a hook at the end they wrench off the cones, breaking a piece of the branch, and a tree which has been subjected to this form of injury for any length of time acquires a ragged appearance.

GERMINATION (Fig. 439, *b-g*). Epigeous. The radicle emerges from the end of the seed and descends ; the hypocotyl elongates, arching but soon straightening and carrying the cotyledons above ground. As the cotyledons elongate the shell of the seed remains enclosing their extremities for a time and then falls to the ground, when the cotyledons, 9–12 in number, spread out in a whorl, from the centre of which the young shoot develops. Sometimes the shell of the seed, which is heavier than in most pines, is not raised above ground but remains on or in the ground, the cotyledons extricating themselves gradually as the hypocotyl elongates.

THE SEEDLING (Fig. 439).

Roots : primary root very long, terete, wiry, brown ; lateral roots numerous, short to moderate in length, fibrous. **Hypocotyl** distinct from root, terete, 1–1.5 in. long, cylindrical, glabrous, at first smooth, pink and pale green, becoming dark green, then brown and striate by the cracking of the epidermis. **Cotyledons** 9–12, whorled, 1.5–2.3 in. long, acicular, triquetrous, compressed laterally, curving upwards, sparsely and minutely serrulate, green. **Stem** erect, wiry. **Leaves** of first season primordial, arranged in a close spiral 0.8–2 in. long, earlier leaves shorter than later ones, acicular, flattened, margins minutely but sharply serrulate.

The growth of the seedling above ground is somewhat slow, but a vigorous taproot is produced early, and may attain a length of as much as 1 ft. by the

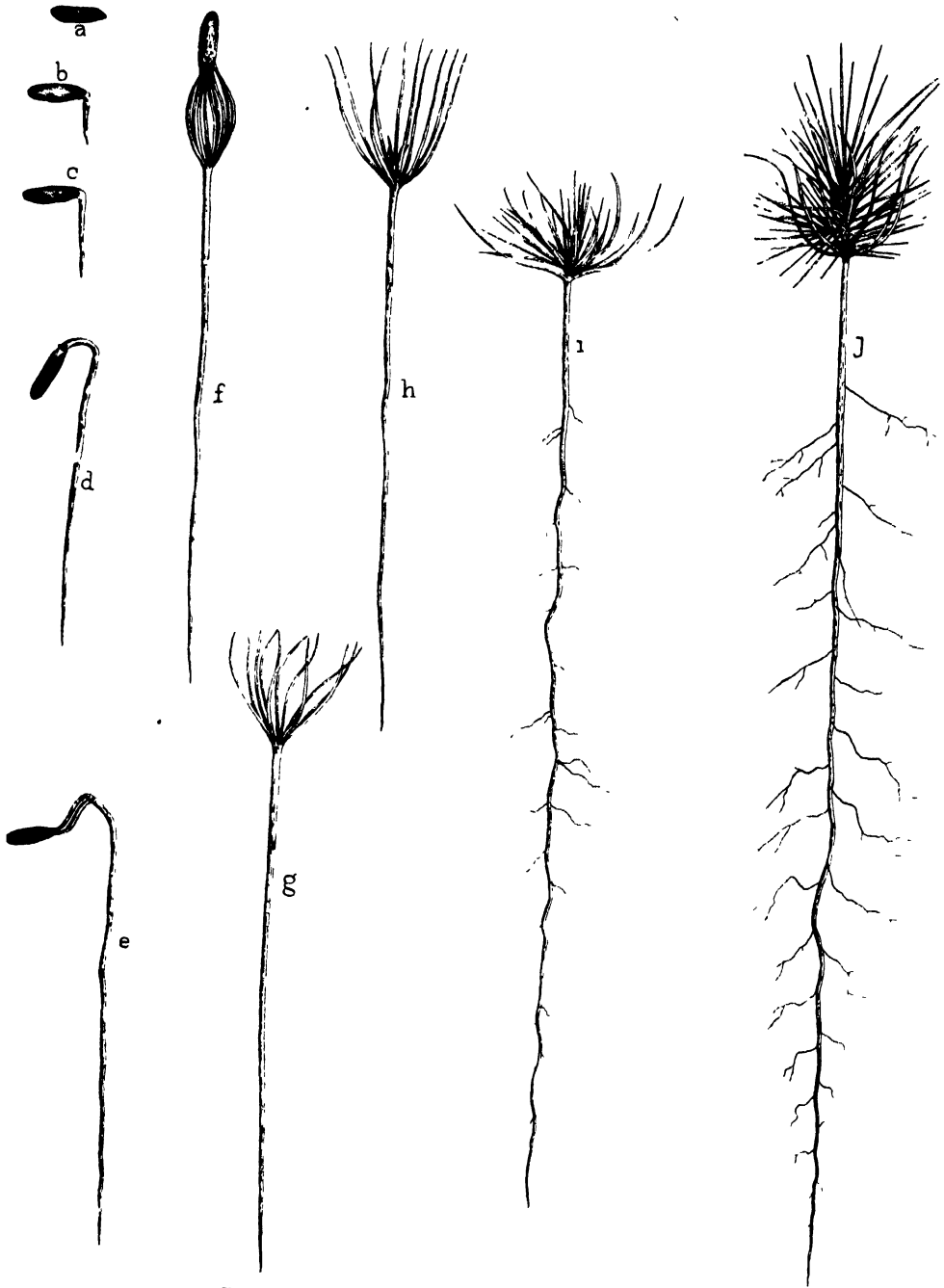


FIG. 439. *Pinus Gerardiana*. Seedling $\times \frac{3}{4}$.

a, seed; b-g, germination stages; h-j, development of seedling to end of first season.

end of the first season. Seedlings raised at Dehra Dun produced a shoot about 1 in. long above the cotyledons during the first season. They were found to be very subject to the attacks of insects, birds, rats, and squirrels

during and shortly after germination, the parts attacked being the tender hypocotyl and cotyledons. The seedling is very intolerant of stiff, badly drained, or wet ground, and requires a free porous soil without any excess of moisture.

SILVICULTURAL CHARACTERS. The chilgoza pine is a light-demander, though perhaps less so than *Pinus longifolia*. It is a hardy tree, standing a considerable degree of cold in winter and excessive drought. It is wind-firm, but on very exposed situations becomes stunted and gnarled. Mr. Stebbing¹ notes that in Zhob bark beetles kill many trees, those attacked showing shot-holes, with resinous exudations, all over. Remedial measures proposed are to select affected trees for felling; to fell them when the insects are in the larval and pupal stages within the tree, about the beginning of June, the middle to the third week of July, the end of August, and the second to third week of October; to remove and burn all bark and to pile up and burn all branch-wood.

NATURAL REPRODUCTION. Where the seeds are extensively collected, natural reproduction suffers from this cause. Mr. Stebbing notes that in the forests of Zhob goat-browsing is very inimical to reproduction, which is scarce in heavily grazed areas, and appears mainly under the protection of thorny thickets, while in places protected from grazing it springs up readily.

SILVICULTURAL TREATMENT. The main object of working the chilgoza pine forests is the production of seed, for which purpose heavy thinnings are indicated where necessary to stimulate the expansion of the crown. In the case of the trans-Indus forests, Mr. Stebbing advocates uneven-aged forest with sowing up of unregenerated blanks and the felling of dead or beetle-infested trees only, a certain proportion of cones being left for natural regeneration. Possibly a system of rotational closures to seed-collection and grazing would also result in successful reproduction.

5. *Pinus Merkusii*, Jungh. Tenasserim pine. Vern. *Tinyu*, Burm.

A moderate-sized to large tree, attaining a height of 100 ft. in Sumatra, but seldom exceeding 60 ft. in Burma. Adult leaves in pairs, 7–10 in. long, enclosed at the base by a persistent sheath 0.6–0.8 in. long. Crown pyramidal in young trees, becoming spreading and umbrella-like in older trees. Bark brownish to ashy grey, thick, fissured. Wood very resinous, used for torches as in the case of *P. Khasya*. The tree produces resin of very good quality (see under *P. Khasya*, p. 1084), and may yet become an important source of supply; resin-tapping operations, however, have not hitherto been organized in the forests of *P. Merkusii*. Occasionally this pine reaches a fair size. Mr. M. H. Ferrars² measured one 9 ft. 7 in. in girth in the hills between the Sittang and Salween rivers.

DISTRIBUTION AND HABITAT. This essentially tropical pine extends from the southern portion of the Southern Shan States southward through the hills of the Salween and Thaungyin drainages. It occurs also in Siam, Cochin China, Sumatra, Java, Borneo, and the Philippines. In the Burmese region it is found at elevations varying from 500 to 2,500 ft., usually on low hills or spurs, associated with *Dipterocarpus tuberculatus* or with *Pentacme suavis*.

¹ Note on the Chilgoza Bark-boring Beetles of Zhob, Baluchistan, For. Bull. No. 3, 1905.

² Ind. Forester, i (1875), p. 114.

Shorea obtusa, and *Melanorrhoea usitata*, often on gravelly soil. It extends over a considerable area in the southern portion of the Southern Shan States (see under *P. Khasya*, p. 1085). In 1885 the area of forests of this pine in the Thaungyin valley was estimated at about 50 square miles, in the neighbourhood of Myawaddi.

Ryan and Kerr¹ say that on the Khoon Youan plateau, Siam, a narrow plateau at an altitude of about 1,500 ft. stretching for 7 or 8 miles, it is the predominant tree, *Dipterocarpus tuberculatus* coming next in order of frequency. The soil is a gravelly sand.

The tree requires very well drained ground and porous soil, and is frequently found on decidedly dry ground, but always in regions of comparatively heavy rainfall. Growing as it often does on the poor dry soil so frequently characteristic of Burmese *indaing* forest, it is not as a rule subjected so much to damage by shifting cultivation as *Pinus Khasya*, though possibly this may to some extent explain the fact that it does not ordinarily form such pure crops as that species in Burma.

In the Philippines, Foxworthy² says, it grows on dry ridges in the provinces of Zambales and Mindoro, and quotes the following field note from the former: 'Grows in pure stands on heights some 15 kilometers east of Santa Cruz, Zambales. Forest of irregular area covering, as estimated, 500 hectares. Soil is loose and impregnated with copper oxide, giving a dark colour. No undergrowth of trees other than pine exists, and fires greatly retard reproduction, so that seedlings are at present rarely found.' Of its occurrence in the Mindoro province Merritt³ says: 'South-west of the high mountain chain stretching north and south from Mount Halcon is an area with a temperature considerably lower than that of sea-level and with a well-drained and extremely dry soil. Here conditions are right for the growth of pine (*P. Merkusii*). This tree grows in pure stands, and is found in open scattered groves along the higher ridges and slopes, sometimes extending well down toward sea-level. This pine was observed at elevations as low as 60 m. in the vicinity of Santa Cruz, the southern part of its range, while at its northern limits it was nowhere seen below 900 m. Ground fires annually burning over the grass which has crept in among these trees prevent the best of reproduction and keep the forest open.'

LEAF-SHEDDING, FLOWERING, AND FRUITING. The new shoots and the flowers appear in February–March, the old needles falling early in the second year (Brandis). Cones ripening April–May, solitary or in pairs, 2–3 in. long or longer, usually curved, ovate oblong with woody oblong scales; apophysis more or less rhomboidal, or 5-gonous on the basal scales, depressed pyramidal, furrowed. Seeds (Fig. 438, *i*) with an unequal-sided wing, the whole 0.8–1 in. long, wings 0.2–0.3 in. broad; seed without wings 0.15–0.25 in. long. About 650–700 seeds weigh 1 oz.

GERMINATION (Fig. 438, *j–o*). Epigeous. The radicle emerges from the end of the seed, the hypocotyl elongates, sometimes with slight arching, and the cotyledons are carried above ground. As the cotyledons, 8–12 in number,

¹ Journ. Siam Soc., viii (1), 1911.

² Philippine Gymnosperms, Philip. Journ. Science, vi, 3, Sec. C, July 1911.

³ The Forests of Mindoro, Philip. For. Bur. Bull. No. 8 (1908), 22.



FIG. 440. *Pinus Gerardiana* trees, upper Sutlej valley.

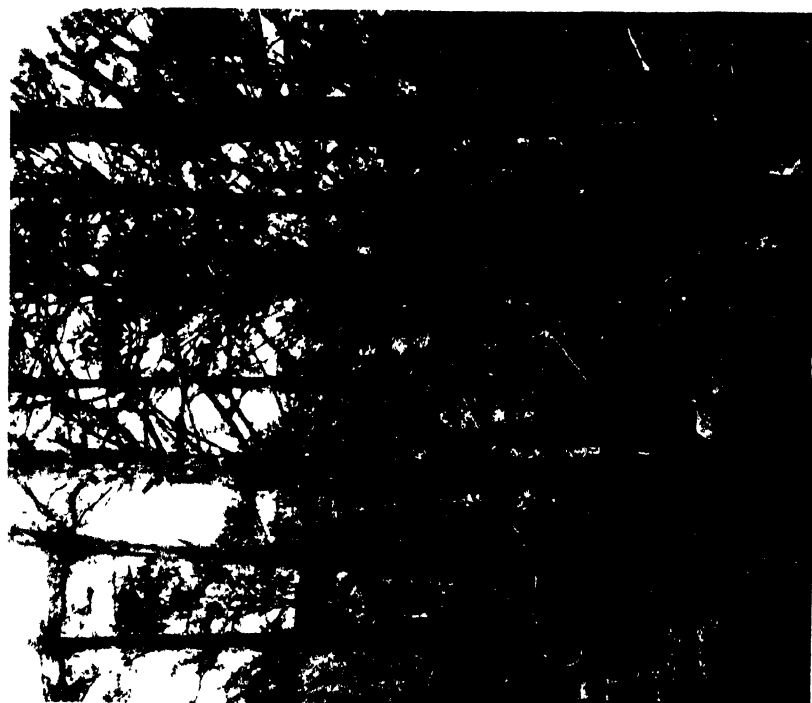


FIG. 441. Pure crop of *Pinus Gerardiana*, upper Sutlej valley.



FIG. 442. *Cedrus Deodara*, large trees in temple grove at Dhungri, Kulu. largest tree 204 ft. high, 17 ft. 4 in. in girth.



FIG. 443. Deodar forest on rocky precipitous ground, Kagan valley, Hazara.

elongate, the shell of the seed remains for a time enclosing their apices like a cap, finally dropping to the ground, when the cotyledons spread out radially and the young shoot develops from the centre of the whorl.

THE SEEDLING (Fig. 438).

Roots: primary root moderately long, wiry, flexuose; lateral roots moderate in number, fibrous. *Hypocotyl* distinct from root, 1.2–1.8 in. long, cylindrical or slightly fusiform, green or reddish turning light brown. *Cotyledons* 8–12, whorled, 1–1.8 in. long, acicular, triquetrous, compressed laterally, light green, inner margin sometimes remotely serrulate. *Stem* erect, terete, in first season pale green and almost hidden by the primordial needles. *Leaves:* first season, only primordial needles, 0.6–1.5 in. long, acicular, flattened above, rounded beneath, punctate in longitudinal lines of stomata, glaucous green, margins finely and sparsely serrulate; second season, adult needles begin to appear, in pairs, 2–7 in. long, inner surfaces flattened, outer rounded, margins finely and sharply serrulate, basal sheath 0.3–0.4 in. long, composed of grey chartaceous scales.

Nothing is known regarding the habits and requirements of the seedling in its natural habitat. Numerous seedlings raised at Dehra Dun showed slow growth during the first season, a height of about 2 in. being ordinarily attained. Few survived the winter frost, and many were destroyed by insects, a form of damage to which they are evidently very prone. The seedlings cannot tolerate stiff, badly drained soil, and require to be grown in free porous soil.

SILVICULTURAL CHARACTERS. The silvicultural characters of this tree require study. Like other pines, it suffers much from fire in its younger stages.

RATE OF GROWTH. Gamble gives the rate of growth as 11 rings per inch of radius, or a mean annual girth increment of 0.57 in.

2. CEDRUS, Link.

The cedars are evergreen trees with branches arising irregularly from the stem, not in whorls. Branchlets of two kinds, namely, long shoots bearing solitary leaves arranged spirally and short arrested shoots with leaves in pseudo-whorls (rosettes). The latter elongate slightly each year, adding a new whorl of leaves, and sometimes produce flowers; occasionally they develop into long shoots. Leaves acicular, rigid, triquetrous. Flowers monoecious or dioecious. Male flowers erect, catkin-like; female flowers small erect cones. Ripe cones solitary, erect, ovoid, ellipsoidal or cylindrical, breaking up on the tree and shedding the winged seeds with the cone scales, the central axis persisting for a long time.

There are three main forms of cedar usually classed as species, which come true from seed: (1) *Cedrus Libani*, Barrelier, the Lebanon cedar, with leading shoot and branchlets not pendulous, broad spreading flat crown, and large broad ellipsoidal cones, indigenous to the Lebanon range and Asia Minor; var. *brevifolia*, Hooker, the Cyprus cedar, a native of Cyprus, has much shorter leaves and cones; (2) *C. atlantica*, Manetti, the Atlas or Algerian cedar, with stiff leader and branchlets, short leaves, and cones shorter and more cylindrical than (1), indigenous to Algeria and Morocco; (3) *C. Deodara*, Loudon, the Himalayan cedar or deodar, with leader and branchlets pendulous on young trees, and with longer leaves and broader cones than the other species.

Cedrus Deodara, Loudon. Syn. *C. Libani*, Barr, var. *Deodara*, Hook. f.; *Pinus Deodara*, Roxb. Himalayan cedar, deodar. Vern. *Diár*, *deodár*, *dedwar*, *kelu*, *kilar*, W. Him.

A very large evergreen tree with dark green, or in some cases silvery, foliage; the form with silvery-blue foliage is conspicuous and handsome, and is fairly common in certain localities, for instance in Hazara. Branches horizontal or slightly ascending or descending, not whorled but arising irregularly from the stem. Extremities of leading shoot and branches drooping in normal young to middle-aged trees, stiffer on stunted slow-growing specimens. Up to middle age the tree has a conical crown with a definite leading shoot, but in later life the crown becomes rounded or broad and flat with spreading horizontal branches, the flat-topped formation being sometimes hastened by injury to the leading shoot or by the action of the wind in exposed situations. Leaves acicular, stiff, 1-1.5 in. long, on the normal long shoots spirally arranged, on the short arrested shoots in pseudo-whorls. On the branchlets the successive years of growth are marked by rings of recurved bud scales marking the points of junction between the successive years' shoots; on the arrested shoots also a fresh ring of small brown recurved scales marks each year's growth. Bark greyish brown, with vertical and diagonal cracks dividing it into irregular oblong scales.

Wood moderately hard; sap-wood white, heart-wood light yellowish brown, oily and strongly scented, very durable. The deodar is the most important timber tree of the western Himalaya. The wood is extensively used for building, railway sleepers, and other purposes for which durability is required, as well as for furniture, general carpentry, and many other purposes; it is largely exported to the plains of India.

The deodar reaches large dimensions. Dr. Schlich found one in the Sutlej valley 240 ft. high, Mr. W. R. Fisher one in the Pabar valley 216 ft. high. Mr. G. G. Minniken¹ records a tree near Purrang village, Bashahr, which was 150 ft. high and 31 ft. 6 in. in girth at 6 ft. from the ground, with a clean bole of 45 ft. to the first branch. Mr. Gamble measured a hollow stump 34 ft. in girth in the Moriru forest, Tehri Garhwal. Brandis mentions trees 30 to 36 ft. in girth in Kunawar. Messrs. Hart and Gibson² record trees in Bashahr measuring 35, 32, and 26 ft. in girth, and mention that 6,158 trees felled for export in the years immediately prior to 1905 averaged 9 ft. 5 in. in girth. Rai Bahadur Keshavanand³ says that 108 selected large trees in well-stocked areas in the Karnah-Drawa forests, Kashmir, gave an average of 11 ft. 4 in. in girth and 125 ft. in height; the largest tree measured was 210 ft. high and 21 ft. in girth. In 1914 I measured a large branchy tree growing on a rock near Monali, Kulu, with a diameter at breast-height of 19 ft. 9 in.; the girth could not be measured owing to the inaccessible position of the tree, but even though the tree had a much greater diameter in one direction than the other, and the greater diameter was measured, the girth cannot have been short of 50 ft. In the Dhungri temple at Monali are some large trees, of which I measured several and found the largest to be 204 ft. high and 17 ft. 4 in. in girth (see Fig. 442). Some of the finest specimens of deodar trees now to be

¹ Ind. Forester, ix (1883), p. 44.

² Working Plan for the Leased Forests of the Bashahr State, Sutlej Valley, 1905.

³ Working Plan for the Karnah-Drawa Forests, Kishanganga Valley, Kashmir.

found are those growing in sacred temple groves, where they are protected from injury and destruction and must in some cases be of great age.

DISTRIBUTION AND HABITAT. *General distribution.* The deodar is found throughout the western Himalaya from Afghanistan to Garhwal at elevations varying from 4,000 to over 10,000 ft., but most commonly at 6,000–8,500 ft. Its eastern natural limit is in the valley of the Dhauli river, a branch of the Alaknanda river in Garhwal, below the Niti pass, longitude $79^{\circ} 48'$. The altitudinal range of what may be termed the deodar belt varies in different localities, while it is usually higher on southerly than on northerly aspects; this belt is a well-marked one, since the tree is essentially gregarious, and often forms pure crops of considerable extent.

The chief deodar forests in British territory are confined to Jaunsar, Kulu, and Hazara, while the aggregate area in Indian states, including Kashmir, Chitral and Dir, Chamba, Bashahr, Tehri Garhwal, as well as various minor hill states, is considerably greater than that in British territory.

In Kashmir the chief zone of the deodar is between 6,500 and 8,000 ft., at which elevations it often forms pure forests; it descends on cool aspects to 5,000 ft., and occasionally to 4,500 ft., while on sunny slopes it may ascend to 10,000 ft. or even higher; at the higher elevations it is usually scattered and stunted. In Hazara, deodar is common in the Kagan valley, its extreme limits of elevation being about 4,000 ft. and 9,000 ft. In the upper parts of the valley, as the rainfall diminishes, it forms purer forests than it does lower down, and although it is frequently mixed with blue pine, spruce, and various broad-leaved species, and at the higher elevations with silver fir, it also forms pure crops of some extent; in the lower parts of the valley it is less plentiful and is usually mixed with other species. Although in places where the soil is deep it attains very fair dimensions, the deodar is not at its best in Hazara, the growth being usually slow and the trees showing a lack of vigour. It is very frequently found on rocky precipitous ground, where it usually forms pure crops (see Fig. 443), and in general it seeks the spurs, while the intervening depressions are occupied by other species. This is the condition in which it is commonly found in the Siran valley, where it is by no means abundant. In the Dungagali and Thandiani ranges it is very local, being found in comparatively small patches, usually at about 7,000–8,000 ft., associated with blue pine, yew, maple, horse-chestnut, and elm, and occasionally with silver fir. The largest tree I have measured in the Kagan valley was one of 21 ft. 6 in. girth in the Kamalban forest; its height, by estimation, was not more than 100 ft. In the Upper Ravi forests of Chamba the most important deodar forests lie between 7,000 and 8,500 ft. In Kulu they lie between 5,000 and 8,000 ft., but the deodar descends in places to 4,500 ft., and ascends to 9,000 ft. or over. In Kangra natural deodar is confined to Chota and Bara Bangahal, and the neighbourhood of Tathwani, where it occurs on a very limited scale. In the upper and drier parts of the Sutlej valley most of the deodar forests occur between 8,500 and 9,500 ft., but trees are found up to 10,000 ft., and occasionally up to 10,500 ft. In lower Bashahr and the Simla hills the principal zone of the deodar lies between 6,000 and 8,000 ft., the extreme limits being approximately 5,500 and 9,500 ft. In Jaunsar and Tehri Garhwal the most important deodar forests lie between 6,500 and 8,500 ft.; on northerly aspects

the tree descends to 6,000 ft. or even lower, while on southerly aspects it ascends to 9,000 ft. or over, though it is stunted at the higher elevations.

Topography, geology, and soil. The deodar occurs naturally on mountainous country with slopes varying from moderate to precipitous, as well as on level ground in river valleys at suitable elevations. It is found on all aspects, though it grows best and reaches its largest dimensions on northerly aspects and in cool situations. It occurs, however, also on hot southerly slopes, though in such places the growth is usually poorer, and the establishment of young growth can as a rule be effected only with the aid of shelter. At the higher elevations it occurs only on sunny aspects.

The deodar is found naturally on all the important geological formations of the western Himalaya, including granite, gneiss, mica and other schists, shale, limestone, quartzite, and conglomerate, as well as on trap dykes and recent boulder beds. It avoids stiff badly drained soil, while on shallow rocky ground the growth is stunted; the best growth is attained on deep, fairly porous, fertile soil in cool situations, for instance along the sides of moist ravines.

Climate. The great majority of the best deodar forests are found where the rainfall varies from 40 to 70 in.; in these regions most of the rain falls during the south-west monsoon from June to September, while there are often considerable falls of snow during the winter, from December to March. The deodar occurs in the inner dry valleys of the upper Sutlej, the Kunhar and Swat rivers, and elsewhere; here the rainfall is probably less than 35 in., the great bulk falling in the form of winter snow, which in these dry regions is an important factor in relation to the deodar. In some of these dry tracts field cultivation is impossible without the aid of irrigation, and this indicates the dryness of the climate in which deodar is capable of growing, though this is probably rendered possible only by the favourable influence of the heavy snowfall. The shade temperature in the deodar zone probably varies for the most part from a minimum of 10° to 25° F. to a maximum of 80° to 100° F.; temperature statistics from stations within that zone, however, are somewhat scanty.

Types of forest. The deodar is a typically gregarious tree, and is frequently found in the form of pure forests. The pure type, which is shown in Figs. 443, 445, and 446, is widely represented throughout the deodar zone, and is especially typical of the inner dry valleys; in the latter regions, however, the trees are often stunted, and usually show very slow growth. Common as are pure crops, it is more usual to find the deodar in mixture with other species, both coniferous and broad-leaved, but in such cases it still tends to retain its gregarious habit, and often forms the bulk of the crop. Among conifers the most important companions of the deodar are the blue pine (*Pinus excelsa*) and the spruce (*Picea Morinda*), the former being as a rule characteristic of drier types of forest than the latter. The deodar-spruce mixture is one in which the deodar often attains excellent height-growth, with a tall, clean bole, since this mixture is frequently characteristic of moist, rich soil; it is well exemplified in the forests of Chamba, but is also frequently met with in Jaunsar, Bashahr, and elsewhere. The mixture of deodar with blue pine is perhaps the commonest met with, and is a most suitable one; it is sometimes found in the form of a deodar underwood making its way up beneath an upper story of blue pine where the latter is sufficiently open. At the higher elevations

the deodar is sometimes found mixed with the silver fir (*Abies Pindrow*), though this mixture is less common than the spruce mixture, and sometimes takes the form of a deodar crop under which the silver fir is gradually making its appearance. Mixed forests of deodar, blue pine, spruce, and silver fir are common in parts of Hazara (see Fig. 399); here the deodar as a rule seeks the more rocky spurs. At the lower elevations deodar is found associated with *Pinus longifolia*, the pine usually occupying the drier ridges and spurs while the deodar occupies the moister and cooler depressions. Sometimes as a result of protection from fire, a young crop of deodar may be found making its appearance beneath an overwood of *Pinus longifolia* (see p. 1055). Where the cypress (*Cupressus torulosa*) is found it is not uncommonly associated with the deodar, while in the dry inner region of the Himalaya the latter is sometimes found with *Pinus Gerardiana*. In moist, shady situations the yew (*Taxus baccata*) sometimes occurs as an underwood species.

Among oaks, *Quercus incana* and *Q. dilatata* are very frequent companions of the deodar, the former at lower elevations than the latter. *Q. dilatata* often occurs in the spruce-deodar mixture in moist situations. At the higher elevations the deodar extends occasionally into the region of *Q. semecarpifolia*, but is hardly typical of that region. In Chitral and the dry parts of the Kishanganga valley in Kashmir and the Kagan valley in Hazara the deodar is associated with *Quercus Ilex*, which sometimes forms a shrubby undergrowth (see Fig. 358).

Besides oaks there are many other broad-leaved species associated with the deodar, for example *Pieris ovalifolia* and *Pyrus Pashia* at low elevations, *Rhododendron arboreum*, *Prunus Padus*, *P. Puddum*, *Aesculus indica*, *Cedrela serrata*, *Populus ciliata*, *Cornus macrophylla*, *C. capitata*, *Juglans regia*, *Ulmus Wallichiana*, *Betula alnoides*, *Corylus Colurna*, *Ilex dipyrena* (in moist situations), and various maples. Among shrubs and small trees of the undergrowth are various species of *Rosa*, *Rubus*, *Lonicera*, *Berberis*, *Viburnum*, *Salix*, *Indigofera*, and *Desmodium*, as well as *Cotoneaster bacillaris*, *Parrotia Jacquemontiana*, *Daphne cannabina*, and other trees and shrubs. Herbaceous plants are common, but the soil-covering in deodar forest not infrequently consists of grass, while in dense pole crops there may be no vegetation at all on the ground. Bamboos are represented by species of *Arundinaria*, of which *A. falcata* and *A. spathiflora* are the commonest. In some localities the bracken fern (*Pteris aquilina*) covers the ground, particularly where the deodar is associated with blue pine. This fern may be regarded as an indicator of soil well suited for both these trees; *Indigofera* and *Desmodium* are also indicators of suitable soil, and on hot aspects form a most useful protective cover for deodar seedlings. Among climbers found in deodar forests the commonest are *Rosa moschata*, *Vitis semicordata*, *Clematis montana*, and ivy (*Hedera Helix*).

LEAF-SHEDDING, FLOWERING, AND FRUITING. The new shoots appear in March or early April, small pale green opening buds marking their first appearance. The old leaves are shed for the most part in the hot season, chiefly in May, but leaf-shedding may also take place to some extent in the autumn, about the time the cones ripen. The persistence of the leaves varies. On vigorous saplings they do not persist so long as on older trees with slow-growing branchlets. In the former case they may all fall the year following

their first appearance, while in the latter case they may persist, in part at least, as long as six years ; this applies both to the whorls of leaves on the arrested branchlets and to the solitary leaves which are spirally arranged on the normal shoots.

Male flowers. The male flowers, sometimes termed catkins (Fig. 444, *a-d*), first appear in June, by the end of which month they become clearly visible at moderate elevations. They ripen and shed their pollen from the middle of September to the middle of October, according to locality and season. The male flowers are solitary and erect at the ends of the arrested branchlets, and are found in quantity along the upper sides of the branches. When young they are pale green. Before ripening they are yellowish green with a purplish tinge, oblong ovoid, 1-1.8 in. long by 0.4-0.6 in. in diameter. On opening they elongate rapidly to 2-3 in. in length, and become yellow with pollen. Trees covered with ripe male flowers show a blaze of yellow on the upper sides of their spreading branches, and the pollen is blown far and wide by the wind, particularly on sunny days, when it may be observed in dense yellow clouds. The majority of the male flowers do not remain long on the tree after ripening, particularly if showers of rain occur to dislodge them, when they fall in quantity to the ground ; some may remain for a few months.

Female flowers. The female flowers or young cones (Fig. 444, *e*) appear in August, and pollination takes place from the middle of September to the middle of October ; they are solitary and erect at the ends of the arrested branchlets on the upper sides of the branches, and usually farther towards their ends than the cones of the previous year. At the time of pollination they are inconspicuous, partly hidden by the rosettes of leaves, and somewhat difficult to find, oblong ovoid, 0.5-0.8 in. long by 0.25 in. in diameter, pale glaucous green. The scales, in spirals of 8×5 , at the time of pollination stand perpendicular to the axis, exposing the ovules, but after pollination they close.

Development and ripening of cones (Fig. 444, *f-h*). There is no growth in the young cones until the following spring, when by the early part of May they have increased sufficiently in size to be clearly visible. By the end of June or during July they become full sized, and are pale bluish green. They turn chocolate-brown in colour during August, and ripen from the end of September to the middle or end of November, though at high elevations or in late seasons the seed may not all fall until the early part of December. Thus the time occupied from the first appearance of the female flower to the ripening of the cone is about $12\frac{1}{2}$ to $13\frac{1}{2}$ months. The ripe cones are erect, brown, ovoid or ellipsoidal, 3-4.5 in. long by 2-3.5 in. in diameter where broadest,

FIG. 444. *Cedrus Deodara*. Flowers and fruit $\times \frac{3}{4}$.

a, young male flower shortly after first appearance : end of June ; *b*, male flower immediately before ripening : September ; *c*, male flower ripening, and pollen emerging : latter part of September ; *d*, male flower completely opened, and pollen shed : end of September and during October ; *e*, female flower (young cone) at time of pollination : latter part of September ; *f*, young female cone beginning to grow : early part of May, seven months after pollination ; *g*, immature cone : June, eight to nine months after pollination ; *h*, ripe cone commencing to open : October, thirteen months after pollination ; *i*, single scale of cone with one seed present (on left) and one removed (on right) ; *j*, winged seed ; *k*, axis of old cone, a year after ripening.

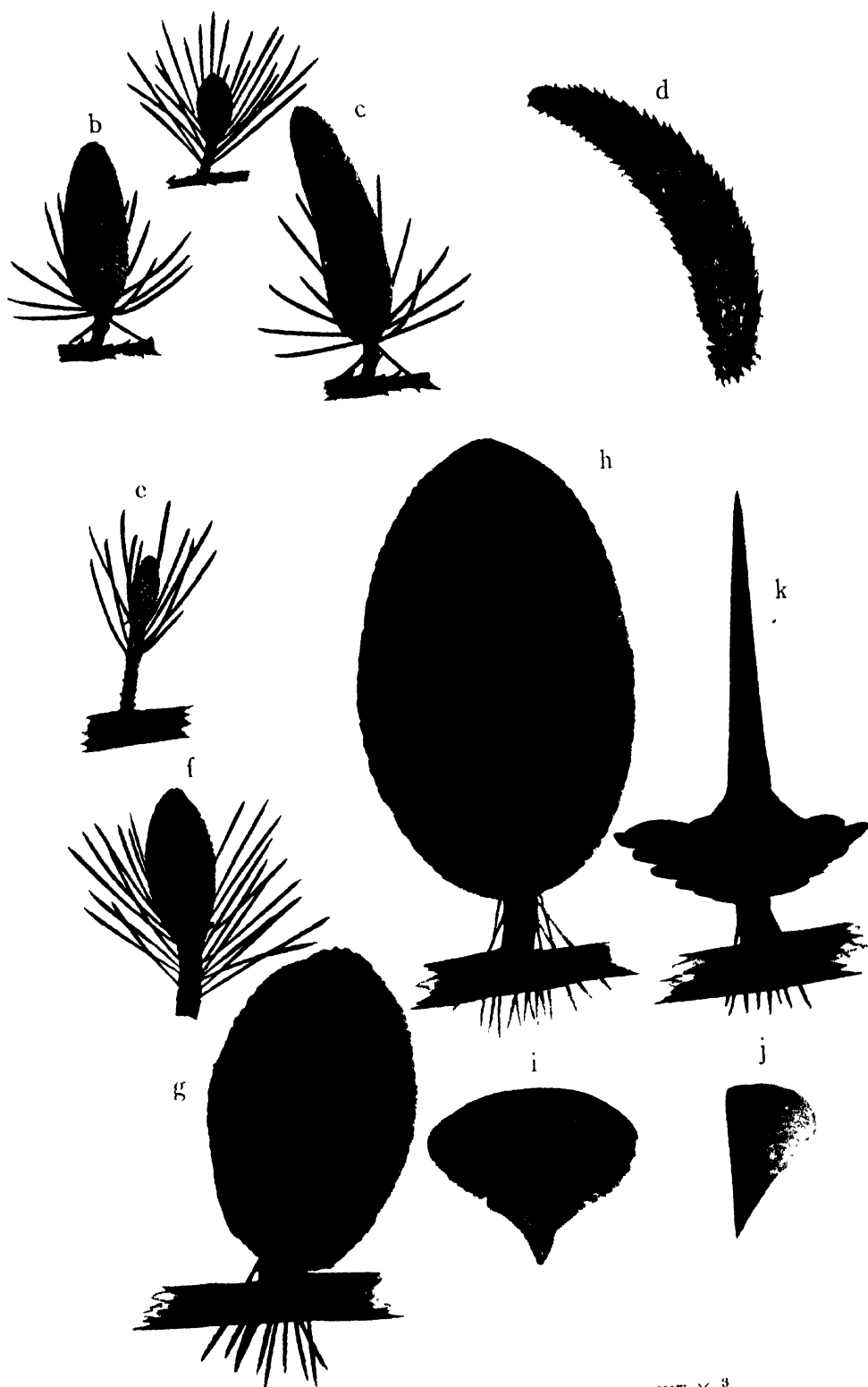


FIG. 444. *Cedrus Deodara*—FLOWERS AND FRUIT $\times \frac{3}{4}$
 For details see footnote page 1100

with numerous fan-shaped scales arranged in spirals of 8×5 on a persistent woody central axis. On each scale rests a pair of winged seeds (Fig. 444, *i* and *j*). On ripening the cone breaks up on the tree, the scales and seeds falling to the ground and the persistent axis remaining (Fig. 444, *k*); these old cone-axes remain for years on the branches. The opening of the cones is favoured by dry, sunny weather. Fig. 447 shows two cones of successive years, namely, a mature cone about to ripen and immediately in front of it a young cone (flower) at the time of pollination; three old cones axes are also visible.

Sexual characters. As a general rule the deodar is dioecious. It is by no means uncommon, however, to find male flowers and female cones on the same tree, in which case, so far as has been observed, they are invariably on separate branches. Several years ago observations were recorded for a series of years in Jaunsar with the view of ascertaining to what extent deodar trees retain their sexual character year after year. The records were unfortunately lost before detailed results could be written up, but it was noticed while the observations lasted that the sex of the trees showed a tendency to remain constant; it is not known if there were any exceptions to the rule. Mr. B. B. Osmaston¹ observed a tree in October 1898 at Konain in Jaunsar, with male catkins on every branch but two, which bore numerous female cones. There were no cones on the male branches. He marked the cone-bearing branches, and these again bore cones in 1900, while there were no cones on the other branches. Although this single case does not afford conclusive evidence, it indicates that, subject to wider verification, there may be a tendency for branches to retain their sexual character. In October 1917 I noticed near Simla a whole group of moderately young trees all exhibiting the same character, namely, the lower branches covered with ripening female cones and the upper branches covered with opening male flowers; the constancy of this character in the several individuals of a whole group, which probably arose from the same seed-bearer, suggests heredity.

Seed and seeding. The seed with wing is 1-1.5 in. long, triangular (Figs. 444, *j*, and 449, *a*); wing with rounded corners, 0.7-1 in. broad; seed without wing 0.35-0.6 in. long, irregularly triangular. About 200 to 260 good seeds, or 230 on an average, weigh 1 oz.

The seeds are oily and soon lose their vitality, but good fresh seed usually shows a high percentage of fertility. The size of the tree appears to have little if any effect on the fertility of the seed, as is shown from the following results of tests, by Mr. R. N. Parker, of seed collected from trees of different sizes:

Girth of tree. ft.	No. of samples tested.	Average germination per cent.
1-2	9	72
2-3	12	86
3-4	12	87
4-5	17	75
5-6	7	82
6-7	8	77
7-8	1	85
8-9	2	82
9-10	1	98

¹ Ind. Forester, xxvi (1900), p. 389.

Cones with fertile seed may be produced in fair quantity at a comparatively early age. Seed from trees thirty-one and forty-five years old, tested at Dehra Dun, showed a fertility of 85 and 95 per cent. respectively. Numerous cones were observed on deodar trees in a plantation twenty-eight years old at Ramgarh Kundi, Kulu, in places where the trees were in fairly open positions, not where the crop was dense.

At one time it was believed that old trees did not produce fertile seed, but this idea has been proved from actual tests to be wrong. The effect of isolation on the seed-bearing capacity of deodar trees is always marked, trees in open positions with well-developed crowns bearing cones in quantity, whereas those in dense crops may bear few or no cones even in a good seed-year.

The collection of seed can best be effected by gathering the cones off the trees immediately before they open, towards the end of September or early in October, placing them in the sun until they open and break up, and shaking and stirring them up in an open-work basket or sieve with mesh large enough to let the seeds through but not the scales. Cones may also be gathered in quantity from felled trees where the felling is done in the autumn. If the cones fall in calm weather a certain amount of seed can be collected from the ground, as seeds and scales often fall together in small masses.

So far as the quantity of seed-bearing trees in a good seed-year is concerned, the effect of sex on natural reproduction has been found to be negligible; in other words, the necessity for retaining female trees is not strong enough to warrant their retention if silvicultural considerations demand otherwise. This fact has been brought out by the results of numerous observations made in 1912 in different parts of the Punjab, from which it was found that in a good seed-year, of 215 trees 6 ft. in girth and over, 167 bore cones and 48 did not, while of 1,039 trees 3 to 6 ft. in girth, 791 bore cones and 248 did not. This gives a ratio of cone-bearing to barren trees of 3.5 to 1 in the case of trees 6 ft. in girth and over and 3.2 to 1 in the case of trees 3 to 6 ft. in girth.

Considering the number of scales in a deodar cone, the number of good seeds is comparatively small. The scales at the base and apex of the cone contain abortive seeds, only the central scales containing well-developed fertile seeds. The cones commence opening in their lower parts, the process of opening proceeding upwards. The small scales at the base of the cone do not open, but usually persist for some time after the remaining scales have fallen (see Fig. 444, *k*). The small scales at the apex do not separate, but fall in a mass. An examination made by me of four cones collected at Konain, Jaunsar, in September 1911 gave the following result :

Cedrus Deodara : result of examination of four cones, Jaunsar, 1911.

No.	Dimensions of cone (length and diameter).	Number of scales with abortive seeds.			Number of central scales with well- formed seeds.		Total scales.
	inches.	Basal.	Apical.	Total.	Scales.	Seeds.	
1	4 × 2.5	45	28	73	86	172	159
2	3.5 × 2.5	53	20	73	117	234	190
3	3.25 × 2	62	24	86	92	184	178
4	4 × 2.75	65	24	89	132	264	221
	Average	56	24	80	107	213	187



FIG. 445. Dense natural pure pole crop of deodar, Jaunsar



FIG. 446. Pure even-aged natural deodar crop of good quality on an area formerly under cultivation, Jaunsar : age 60 years, mean girth 5 ft. 7 in., mean height 122 ft



FIG. 447. *Cedrus Deodara*, female cone about to ripen, female flower at time of pollination (in front of cone), and two old cone axes, one-third natural size.

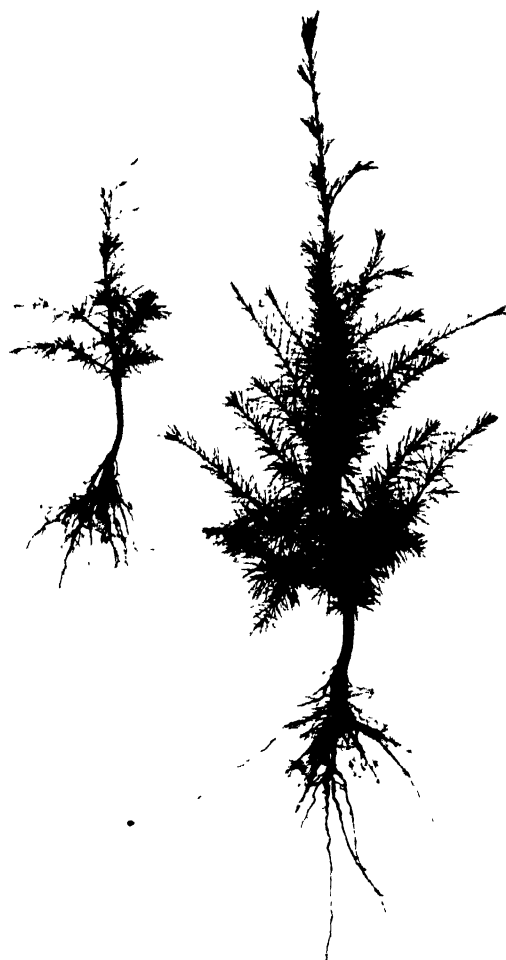


FIG. 448. *Cedrus Deodara*, two nursery plants 3 years old, the larger 3 ft. 3 in. from top of shoot to end of root.

An examination of a cone by Mr. B. B. Osmaston in 1900 showed 94 basal and 25 apical scales with abortive seeds, and 100 central scales with 90 good and 110 bad seeds; the whole cone had 219 scales with 438 seeds, of which 90 were good.

The following figures show the results of an examination made by Mr. R. N. Parker of cones from five ranges of Bashahr :

Cedrus Deodara : result of examination of cones from Bashahr.

	Pabar range.				Nogli range.				Taranda range.			Pandrabis range.				Kilba range.			
Girth of tree (inches)	18	21	29	35	18	21	29	36	20	30	36	16	21	25	32	17	22	27	34
Number of cones examined	5	7	6	6	4	7	8	7	6	6	5	3	6	7	6	7	6	7	7
Average number of fully developed seeds per cone	1.4	2.0	3.5	2.8	1.0	0.7	2.1	1.3	51 (18)	37 (?)	86 (23)	61 (2)	50 (9)	78 (16)	91 (16)	69 (3)	51 (7)	81 (20)	101 (6)
Average germination per cent.	73				83				76			85				80			

The figures in brackets are the numbers of fully developed seeds attacked by insects.

The small number of good seeds in the Pabar and Nogli ranges is noteworthy. In these two ranges the seed-year was a poor one, while in the other three ranges it was fair to good. The inference is that in a poor seed-year the proportion of good seeds per cone is small; if this is sometimes the case, however, it is apparently not always so, as the four cones noted above from Konain were collected in a poor seed-year, and they contained a comparatively large proportion of well-developed seeds.

The following table gives a summary of available records of seed-years in different parts of the western Himalaya :

Cedrus Deodara : records of seed-years, western Himalaya.

Locality.	Total period.	Number of years for which records are actually available.	State of seed-year. Good to abundant.	Periodicity of good seed-years. Poor to partial.
Jaunsar	1879 to 1916—38 years	36	12	24 1 in 3 years.
Bashahr	1873 to 1882 } 1905 to 1913 } 19 years	18	7	11 1 in 2.6 years.
Kulu	1872 to 1882 } 1905 to 1909 } 16 years	16	6	10 1 in 2.7 years.
Hazara	1905 to 1914—10 years	9	3	6 1 in 3 years.

It would appear from these records that the average periodicity of good seed-years may be taken at about one in three. The state of a seed-year may vary within comparatively narrow local ranges, an abundant crop being produced in one small locality, while in an adjacent locality not far distant the crop may be poor. In some years abundant seeding or failure to seed has been recorded consistently throughout almost the whole of the western Himalaya. Partial seeding, that is, where only a moderate number of cones are produced or where only a portion of the female trees produce cones, is frequent; indeed a complete lack of cones over any extent of area is comparatively rare.

The probable state of seeding in any year can be easily foretold early in

May of the year in question, that is, about five to six months before the cones ripen; by this time the young pale green cones have reached a length of 1-2 in., and are clearly visible on the trees. During the previous autumn and winter the young cones, though present, are so small that they cannot be distinguished from any distance.

Among pests which destroy the seed of the deodar the worst is the larva of a small brown moth, *Euzophera cedrella*, Hampson. The attack is noticeable on the half-grown green cones about July. The larva bores into the cones, making small round tunnels, the entrances to which are filled with excreta, much resin exuding. The scales and seeds in the neighbourhood of the tunnels become covered with resin, and even when the insect does not actually bore through the seeds those in the neighbourhood become saturated with resin, turning black and becoming infertile. Frequently the whole of the inside of the cone is eaten out, and in years of severe attack almost the entire seed-crop may be destroyed. The larva is full grown by the end of July, when it is about 1 in. long; pupation takes place in August, and the imago hatches out from September to November, in time to lay its eggs in the young cones when they first appear.

Among birds, the most destructive are jays and nutcrackers, which attack the unripe cones from early September onwards, tearing off the scales and devouring the seeds. They continue their attacks throughout the period of ripening, destroying considerable quantities of seed. During the winter months seed lying on the ground is devoured by pheasants.

GERMINATION (Fig. 449, *b-g*). Epigeous. The radicle emerges from the apex of the seed, opposite the wing, and descends. The hypocotyl, at first curving downwards or slightly arching, straightens in elongating, and raises above ground the cotyledons enclosed in the shell of the seed, to which the wing usually remains attached. As the cotyledons elongate, their apices remain enclosed in the oily endosperm within the shell of the seed, until finally the latter falls to the ground and the cotyledons, 9-11 in number, spread out in a whorl, from the centre of which the young shoot subsequently develops. In rare cases the shell of the seed remains underground, the hypocotyl arching and the cotyledons being gradually extricated.

The seedling. The following is a description of the seedling during the first three years:

First year (Fig. 449, *h*). *Roots*: primary root long, thin, tapering, wiry, dark brown; lateral roots, if present, few to moderate in number, short, fibrous. *Hypocotyl* distinct from root, 1.3-2.5 in. long, cylindrical, glabrous, at first reddish green and smooth, soon turning brown, wiry and striate by splitting of the epidermis; point of junction between hypocotyl and root marked in early stages by the loose prolongation of the ruptured root-epidermis. *Cotyledons* 9-11, whorled, 1.2-1.7 in. long, curving upwards, acicular, triquetrous, compressed laterally, glaucous green, often turning brown and commencing to fall by the end of the season. *Shoot* (above cotyledons) pale buff-coloured, with numerous spirally arranged leaves and often with one or more yellowish brown lateral buds, or in specially vigorous plants one or more arrested branchlets with pseudo-whorls of leaves may have formed. *Leaves* 0.6-1.3 in. long, usually not more than 1 in. long in natural seedlings, those of arrested branchlets, if present, much shorter, acicular, triquetrous, glaucous green.

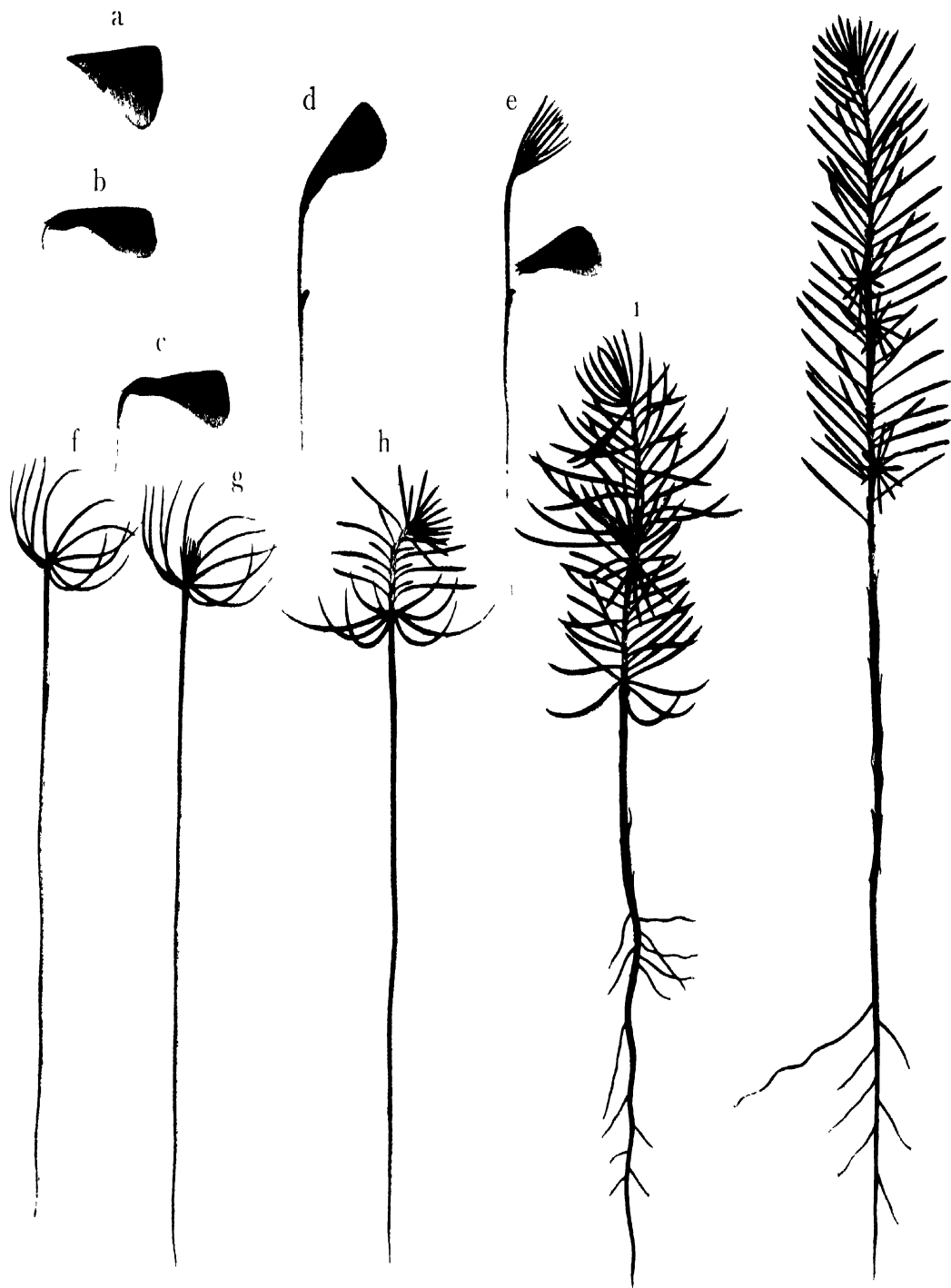


FIG. 449. *Cedrus Deodura* SEEDLING $\times \frac{1}{2}$

a Seed b - g—Germination stages (d and e show ruptured epidermis at base of hypocotyl)
 h—Natural seedling at end of first season i Natural seedling at end of second season
 j—Natural seedling at end of third season

Second year (Fig. 449, i). *Roots*: primary root tapering, wiry, thick in vigorous seedlings; lateral roots fairly numerous, short to moderately long, fibrous. *Hypocotyl* greyish brown, smooth or exfoliating in longitudinal strips. *Cotyledons* usually fallen by end of season, their position well marked by a raised ring. *Stem*: first year's shoot (above cotyledons) silvery grey to greenish grey, covered with spirally arranged green, not markedly glaucous leaves: second year's shoot pale yellowish or greenish buff, with numerous spirally arranged glaucous leaves 0.7–1.3 in. long, more crowded towards the apex. *Buds*: terminal bud small, light brown, that of previous year's shoot well marked by a ring of persistent brown recurved scales; lateral buds one or more in the axils of the leaves. *Branches*: one or more arrested branchlets bearing pseudo-whorls of leaves usually occur along the stem; one or more side branches frequently develop, especially on vigorous seedlings.

Third year (Fig. 449, j). *Roots*: primary root thick, tapering, woody, often not well marked in nursery seedlings, which have a strong bushy root-system; lateral roots numerous, fibrous, short to long. *Hypocotyl* greyish brown, smooth or exfoliating in longitudinal strips. *Cotyledons* absent, their position well marked by a raised ring. *Stem*: first year's shoot (above cotyledons) silvery grey to greenish grey with spirally arranged leaves either present in quantity or nearly all fallen, the shedding commencing at the bottom; leaves green, not glaucous, often turning yellow or brown; spiral raised leaf-insertions (pulvini) conspicuous after the leaves fall: second year's shoot silvery greenish grey, with spirally arranged leaves still present, green, not markedly glaucous, some leaves often shed: third year's shoot pale yellowish or greenish buff, with numerous spirally arranged glaucous leaves up to 1.5 in. long, more crowded towards the apex. *Buds*: terminal bud small, light brown, former terminal buds of first and second years' shoots well marked by rings of persistent brown recurved scales; lateral buds one or more in the axils of the leaves. *Branches*: arrested branchlets bearing pseudo-whorls of leaves usually occur at intervals along the main stem; vigorous seedlings often have side branches, sometimes in quantity.

The rate of growth of the seedling varies greatly according to the conditions under which it is grown. In the first season natural seedlings ordinarily produce shoots 0.5–1 in. long above the cotyledons, giving a total height of about 2–3.5 in., but vigorous nursery seedlings produce shoots 4–5 in. or more in length, giving, with the hypocotyl, a height up to 7 in. or more. Subsequent growth of natural seedlings is usually at the rate of about 1–2 in. per annum for a few years, while nursery plants three years old attain a height of under 1 ft. to over 2 ft., averaging about 15–18 in. Fig. 448 shows two nursery plants three years old. Seedlings show striking development on the ashes of burnt débris, where they may attain a height of as much as 8 in. in the first season. The age of seedlings can be determined without much difficulty, since the points of junction between the successive years' shoots are marked by the rings of recurved scales of the former terminal buds, which persist for a few years; the first of these rings will be found some little distance above the raised ring marking the insertion of the cotyledons. In determining the age of trees by ring-countings it is safe to add ten years for the time taken for a natural seedling to reach stump height.

The persistence of the leaves of seedlings varies; in vigorous plants they may be shed in part during the second year and wholly during the third year, while in plants of slower growth they may persist for four or even five years.

On rocky ground natural seedlings tend to form a long, wiry taproot. In the case of nursery plants, pricking out arrests the taproot and causes the

formation of a strong, bushy root-system which attains a length of about 6-18 in. in three years.

Seedlings are very sensitive to drought, which is the cause of extensive mortality on dry sunny situations ; in such places a certain amount of protection from the sun is essential. Young plants endure moderate shade, but after establishing themselves they require full overhead light for their best development ; in cool, moist situations they grow best with complete light from the commencement.

In the Himalaya seedlings do not ordinarily suffer from frost except in frosty hollows, but in Britain they are somewhat tender. Hail has been known to kill large quantities of seedlings in sowings in Jaunsar.

Young plants suffer much from the attacks of insects, particularly cockchafer grubs, which destroy the roots, and cutworms (*Agrotis ypsilon*), which bite through the roots and stems.

SILVICULTURAL CHARACTERS. Although young deodar plants are capable of standing moderate shade and of persisting under it for some time, they are incapable of making satisfactory headway unless afforded complete overhead light. After the first two or three years, during which protection from the desiccating effect of the sun is advantageous on hot aspects, overhead light is essential to proper development. Plants in a state of suppression can at once be recognized by the absence of a vigorous leader and a characteristic flat-topped appearance ; such plants, although they may persist for many years, are too far gone to benefit by the admission of light. The deodar may be classed as a light-demander rather than a shade-bearer, in that it requires complete overhead light ; it will, however, stand much shade from the side, and in order to produce a clean bole it should be grown in a fairly dense crop. Some of the finest deodar timber is produced in mixture with the spruce, which affords dense lateral shade, causing the production of an exceptionally clean bole in the deodar.

The deodar is affected by drought chiefly in the seedling stage. If it survives the earlier years it has little to fear later, though on dry rocky ground it reaches physical maturity at an earlier age than elsewhere, and becomes dry-topped. Wind does not as a rule do much damage in deodar crops, as the tree has a massive root-system ; on loose, shaly soil, however, windfalls are not infrequent, while on exposed ridges the trees become stunted and misshapen. The deodar is seldom affected by frost in its natural home, but in England it suffers severely.

Snow is the cause of serious injury in many parts of the Himalayan region. Although not quite so fragile as *Pinus excelsa*, the deodar suffers considerably from snow, poles being bent, broken, or uprooted. This form of injury is commonest in pole crops which have been left unthinned too long. Thinnings deferred too long and then carried out only intensify the damage, and the only effective means of reducing snow damage to a minimum is to start thinnings at an early age and to execute them lightly and at frequent intervals.

Fire seldom enters the moister types of deodar forest, but it may do extensive damage in the drier types. Khan Bahadur Imam ud Din¹ notes the case of a dense forest of pure deodar at Sanjiret in Chitral, in which he

¹ Report on the Chitral Forest, 1908.

found some 10,000 dead trees of all sizes ; these had been killed by a fire which occurred eight years previously. Some remarkable effects of fire-protection may be seen in Jaunsar towards the lower limit of the deodar, where it meets the *Pinus longifolia* zone. Here the introduction of fire-protection has caused the spread of the deodar downwards in great quantity into the region of the pine, forming in places dense young crops, sometimes pure, sometimes mixed with blue pine (*Pinus excelsa*) and chir pine (*P. longifolia*), underneath somewhat open pure crops of large *P. longifolia* trees (see Fig. 450) ; this indicates that the deodar is more sensitive to fire than the chir pine, for as long as these areas were subject to burning the pine held the ground. The effect of fire on natural reproduction is discussed below.

Browsing by goats is the cause of much injury to young deodar. When the browsing is light and there is a plentiful supply of *Indigofera* and other palatable plants the deodar escapes without much harm, but where it is heavy, as is frequently the case, the deodar is browsed down to bush-like form and kept in this condition. Lopping for the sake of litter and manure is a very common form of injury to which the deodar is subjected. Trees which have been systematically lopped for some time present the appearance of straight poles covered throughout their length with bushy shoots ; cone-production is prevented and natural regeneration thus ceases, while the lopped trees die off by degrees, and treeless grassy slopes take the place of well-wooded hill-sides. This process of destruction can be observed in all stages in many parts of the Himalaya.

Among wild animals, bears, porcupines, and monkeys are the most injurious. Bears remove the bark of deodar poles and saplings with their teeth and claws, presumably to lick the resinous surface beneath ; in some localities the damage done in this way is extensive, many young trees being completely girdled and killed. Porcupines do similar damage by gnawing off the bark round the base of the trees. In some localities langur monkeys do much damage by gnawing the bark from poles and saplings, while they, as well as brown monkeys, have a habit of pulling up germinating deodar seedlings.

Among climbers in deodar forest the worst is *Rosa moschata*, which scrambles into the crowns of young trees and suppresses them. *Vitis semicordata* and *Hedera Helix* as a rule do less damage, while *Clematis montana* is seldom luxuriant enough to be the cause of much injury.

Among parasitic fungi there are two which are particularly injurious to the deodar ; these are *Fomes annosus*, Fries (*Trametes radiciperda*, Hartig), and *Peridermium* (*Aecidium*) *Cedri*, Barcl. The former is considered by Hartig to be the most dangerous enemy of coniferous trees in northern Europe ; it is a serious menace to deodar crops in some parts of the Himalaya, and has been spreading in the plantations of Kulu within recent years. In the case of the deodar, young trees appear to be most prone to attack. This fungus spreads centrifugally, attacking the roots, which become rotten, the bark cracking and white bands and sheets of mycelium being found beneath the scales. The mycelium ascends from the roots along the cambium into the lower part of the stem, which shows an exudation of resin, and the needles turn yellow and fall ; when the mycelium has encircled the stem the tree dies. The wood is also attacked by fine hyphae, which disintegrate the tissues,

reducing the value of the timber. The sporophores appear on the lower part of the stem in the form of brown rounded nodules, which increase and cohere into irregular brown incrustations with numerous ledges, the lower spore-bearing surface of which is at first white and later turns brown. According to Butler,¹ rhizomorphs are also produced, which is not the case in Europe; they are dark brown or nearly black, and resemble fine roots. These rhizomorphs, which are the organs of vegetative reproduction and are produced in large numbers, are probably the chief means by which the fungus spreads underground from root to root. The only practicable method of preventing the spread of the fungus appears to be by trenching round affected trees or groups of trees and isolating them.

Peridermium Cedri, Barcl., is the aecidial form of a fungus which does extensive damage in some localities.² The fungus attacks the young needles of the current year's shoots. The first sign of the attack is seen in the spring, when the affected needles are noticed to be shorter than the normal ones and curved backwards. About May and June numerous small yellow aecidia appear on the surface of the needles and subsequently burst, emitting clouds of yellow spores. The curved form of the needles persists throughout the year, long after the spores are shed. The foliage becomes thin, and the twigs and afterwards the branches die. One of the most characteristic results of an attack of this fungus is the production of 'witches' brooms', which are often the most conspicuous outward sign of the attack; these witches' brooms, however, are not always present.

When the attack consists of nothing more than a few witches' brooms on side branches, little or no damage results to the tree affected, although such a tree is always dangerous as a centre of infection. Extensive damage, however, sometimes occurs in young and middle-aged deodar crops. A mysterious disease, which had for years been killing off poles in large numbers in the plantations round Monali in the Beas valley, Kulu, I found in 1914 to be none other than a severe attack of this fungus; these plantations are situated in a rather moist valley at an elevation of 6,000 ft., a locality probably favourable to the spread of the fungus. Up to 1914 some hundreds of diseased stems had been cut out; in that year many more were observed to be dying, while of the survivors it was estimated that at least 80 per cent. were visibly affected. In these plantations the appearance of the attack is characteristic. The foliage becomes thin below the leader, and the twigs, and afterwards the larger branches, commence to die. The leader remains alive for a time but eventually dies, and as the attack spreads the whole tree dies. In Jaunsar damage almost as severe has been noticed in natural pole crops at Koti Kanasar, where numerous poles were found in 1911 to be badly forked and misshapen at the top, and had to be cut out in thinnings. Even young crops may be affected. A plantation only three years old at Kathiyan in Jaunsar was found some years ago to contain several plants so badly attacked as to have the appearance of witches' brooms growing out of the ground; the leading shoots had been destroyed, and the affected plants were doomed to perish.

This fungus requires further study. The spores, which escape in May

¹ Ind. Forester, xxxi (1905), p. 489.

² See *ibid.*, xxxviii (1912), p. 222, and xl (1914), p. 469.

and June and are wind-borne, apparently germinate on the young shoots ; the mycelium probably spreads into the next year's young needles in the following spring, since the fructifications appear on these needles next May. Once the disease has gained a hold it is practically impossible to deal with it, since its facilities for spreading are so great. Where it first makes its appearance in a locality or plantation it could possibly be dealt with by cutting off and burning affected branches. Preventive measures would consist of avoiding damp valleys for deodar plantations and mixing deodar with blue pine or other suitable species.

So far as I have had an opportunity of observing the prevalence of this fungus, it is locally common in Jaunsar, the Simla hills, Bashahr, the Inner and Outer Saraj in Kulu, and the Kagan valley in Hazara, and is abundant in the Beas valley in Kulu.

Mr. J. S. Gamble informs me that his deodar plantations in Hampshire, England, have suffered much from the attacks of *Armillaria mellea*, probably the result of damage done to the roots by a bad storm soon after the plantations were formed ; he says that plants mixed with broad-leaved species have suffered less than those mixed with other conifers.

NATURAL REPRODUCTION. The natural reproduction of the deodar can best be studied by considering the various factors which influence it, and these may be conveniently grouped under (1) seeding conditions, (2) germination, (3) climatic conditions, (4) conditions of soil and soil-covering, (5) light, (6) miscellaneous factors. Actual instances of the manner in which natural reproduction makes its appearance under different conditions can best be considered in connexion with regenerative measures, and these are accordingly dealt with later under 'silvicultural treatment'.

1. *Seeding conditions.* It has already been noted that normally one year in every three is a good seed-year, and the ratio of cone-bearing to male trees is large enough to ensure in good seed-years a plentiful supply of seed. Fertile seed is produced by comparatively young trees as well as by old trees ; instances have been observed of abundant natural reproduction springing up under open pole crops (i) averaging 2½ ft. in girth at Koti Kanasar in Jaunsar, (ii) averaging 3 ft. in girth near Naggar in Kulu, (iii) averaging 4 ft. in girth in the same locality. Many similar instances could no doubt be quoted elsewhere. Crown development is of more importance than the actual size of the seed-bearers, since trees in open positions with well-developed crowns produce seed in greater abundance than those grown in close canopy or those subjected to systematic lopping. With a sufficiency of suitable seed-bearers seed is produced in quantity sufficient to carpet the ground in the vicinity with a thick growth of young plants if other conditions are favourable. Much of the seed produced falls along with the cone-scales beneath or close around the trees, and only a comparatively small proportion travels some distance before reaching the ground ; in this respect the deodar differs from the pines associated with it, whose seeds escape singly from the cones and may be blown to considerable distances. In the case of the deodar natural seedlings may be found individually or even in moderate quantity at some distance from seed-bearers, particularly on the downhill side, but dense crops of natural reproduction spring up within a much more limited radius of the seed-bearers than is the

case with the pines. The actual radius within which dense natural crops are capable of springing up must depend on local circumstances such as the slope, and the strength and direction of breezes at the time of seeding.

2. *Germination.* Given the necessary minimum of moisture the seed, which has lain on the ground through the winter, germinates in the following spring, earlier than in the case of any other western Himalayan conifer. As a general rule germination takes place during March and April ; under heavy shade or in cold situations it may be delayed until May, but in warm situations and in warm seasons it may commence in February or even as early as January. Germinating seedlings have been found beneath snow. Germination actually takes place under all conditions of cover, in the densest shade as well as in places completely exposed to the sun, in deep, moist, fertile soil as well as on bare rock, and in good seed-years germinating seedlings may be found in countless numbers in all kinds of situations in the neighbourhood of seed-bearers of all sizes ; even under favourable conditions, however, numbers of these seedlings perish from one cause or another, and where the conditions are adverse, the holocaust of seedlings may result in not a single one remaining by the end of the season. *

3. *Climatic conditions.* Drought is probably the most adverse factor with which the deodar seedling has to contend in its earlier stages ; this factor is largely responsible for the high mortality so prevalent among natural seedlings during the first season. Where the monsoon influence is felt the critical times are from April to June and again from September to November ; during these two periods seedlings may be found dying of drought in quantity in dry or exposed situations and in dry seasons, while similar mortality may be observed between June and September in seasons of scanty monsoon rain. In the dry regions beyond the influence of the monsoon the seedling has to rely for its existence on a heavy snowfall in the winter, which supplies sufficient moisture in the soil to tide over the intervening period of drought. Although the influence of snow on the natural reproduction of the deodar has as yet been insufficiently studied, it may be safely said that it is of great importance, not only in regions out of reach of the monsoon, but also in regions subject to monsoon influence. Its beneficial effect lies in protecting the seed from birds and animals during the winter and in supplying sufficient moisture to the soil, after it melts, to counteract the adverse effects of the subsequent period of drought. It has been noticed in the case of artificial sowings that a year of scanty snowfall may be followed next spring by early germination and the subsequent wholesale death of the seedlings during the dry weather from April to June. The natural reproduction of deodar in the inner dry regions is often profuse. Although the rainfall there is so scanty as to be quite incapable of securing the survival of natural seedlings to any extent, the winter snowfall is heavy, and the inference is that the natural reproduction must owe its success to a large extent to the effect of the snow, though the absence of heavy undergrowth no doubt also favours it.

To summarize, it may be stated that a season of heavy snowfall or plentiful and well-distributed rainfall following a good seed-year is of great benefit to natural reproduction, whereas a season of drought may nullify all the effects of an abundant seed-year. *

4. *Conditions of soil and soil-covering.* It has just been pointed out that a desiccated condition of the soil, which may be due to climatic or to other causes, is probably the most adverse factor with which the deodar seedling has to contend ; it follows that anything which will either reduce soil desiccation or so stimulate the growth of the seedling as to cause the rapid penetration of the taproot to the moister layers of the mineral soil at some depth below the surface, will act favourably on the establishment of natural reproduction. The profusion with which deodar reproduction springs up and establishes itself on newly exposed mineral soil—for instance on abandoned cultivation, road cuttings, landslips, taluses, and occasionally on the sand and shingle of river-beds—demonstrates the advantages secured by the direct contact of the young taproot with, and its unimpeded development in, the mineral soil. Free porous soil, provided there is sufficient moisture present, is favourable, while stiff, hard soil is the reverse, for in the former a vigorous development of the root-system is possible, whereas in the latter its feeble development greatly enhances the risk of death from drought. Soil hardened by the tread of grazing animals is particularly unfavourable to natural reproduction. The effects of desiccation in preventing natural reproduction are well exemplified on shallow soil where the underlying rock is near the surface, particularly on hot aspects ; here reproduction may be abundant all round, but all efforts will fail to induce it to appear where the rock is only thinly covered with soil. Some rocks are more inhospitable than others in this respect ; limestone, which decomposes slowly and is very permeable, producing a dry surface soil, is one of the worst, while friable mica schist and soft shale are more favourable.

The effects of desiccation are intensified where the young taproot has to make its way through a thick layer of raw humus in the shape of undecayed needles. Raw humus absorbs water readily, but parts with it rapidly, and in dry situations and in periods of drought it constitutes a dry stratum through which the taproot of the seedling is unable to make its way before it perishes from lack of moisture. The effect of the removal of raw humus is strikingly illustrated in some of the forests of Kulu, where the right exists to remove litter for the manuring of rice-fields. This removal is effected by scraping off the layer of needles with an iron rake, the mineral soil being completely exposed. On such ground young deodar seedlings appear in vast quantities after a good seed-year ; these are regularly destroyed within a year or two by the scraping action of the rakes, but if the removal of litter is prevented for some years after a good seed-year, complete regeneration can be secured at once if the crop is opened out to give favourable light conditions.

Apart from the action of raw humus, there are other adverse soil factors whose nature is not clearly understood. It has often been noticed that reproduction fails in moist depressions, although it may be abundant on better drained ground in close proximity ; it is likewise often absent in moist types of forest such as those in which deodar is mixed with spruce or silver fir on cool aspects. Such a condition has been variously attributed to bad drainage, and to excess of organic matter, of carbon dioxide, or of moisture. The injurious factor, although possibly connected with an excess of moisture, cannot be merely water as such, for an instance has been observed in a valley below

Simla, in which numerous deodar seedlings about three years old were growing vigorously along the side of a perennial running stream on ground constantly saturated with water and covered with bog moss. Whatever the precise nature of the injurious factor may be, it can be dissipated by the action of fire and by the aeration of the soil. During the rainy season seedlings tend to rot off in damp situations where the weed-growth is heavy.

Failure in natural reproduction is often attributable to the mechanical action of an accumulation of refuse resulting from felling and conversion, in the shape of chips of wood, fragments of bark, and heaps of sawdust and brushwood; germination may take place on heaps of such refuse, but the seedlings quickly perish. Where fellings are heavy these accumulations of refuse may account for a good deal of failure to secure reproduction. The measures adopted with success in Kulu for removing this refuse, by burning and thereby producing an excellent germinating bed, are described later.

A soil-covering of herbaceous or shrubby plants may be injurious or beneficial. A dense growth of grass with a matted root-system may prevent the taproots of deodar seedlings from penetrating readily to the mineral soil, and may thus cause their death from drought. The presence of grass, however, is by no means always an adverse factor; on hot slopes it may exercise a protective influence provided it is not too dense and matted, and cases are often to be found of deodar reproduction establishing itself well on grassy areas. In moist localities heavy weed-growth causes suppression or produces unfavourable soil conditions, preventing the establishment of reproduction. On hot aspects, however, the protection afforded by a soil-covering of shrubs is of great benefit, and may be essential to the survival of deodar seedlings. Among the most useful shrubs in this respect are species of *Indigofera* and *Desmodium*, while the bracken fern is also a useful protection. The protective effect of tree-growth is dealt with below under 'silvicultural treatment'.

5. *Light*. If light were the only factor to be considered, then it might be said at once that the best results would be obtained by complete exposure from the time of germination onwards; wherever conditions will permit of this, deodar plants grow more vigorously when free from all cover than when even lightly shaded. It is only the fear of desiccation that renders shade necessary at all during the first few years of the seedling's life, and it is only in places where desiccation is to be feared that any form of cover which impedes the admission of abundant light is necessary, while even then the cover should not be retained longer than it is required. On cool aspects and moist fertile porous soil the natural reproduction of deodar is often all that can be desired where there is no sort of cover from the commencement. Some of the best deodar reproduction to be found anywhere is that which has sprung up on abandoned fields in the open; here the well-tilled ground produces favourable soil conditions, that is, good aeration and conservation of moisture, promoting vigorous development in the seedlings and thus ensuring them against injury from desiccation without the aid of any protective cover. Mr. Trevor¹ notes that in the Jutlikalwala plantation in Kulu the height of deodar growing in the full enjoyment of light was found to be double that of plants growing under a light overwood of blue pine; also

¹ Ind. Forester, xli (1915), p. 451.

that in the Trai Jakar plantation deodar plants seven years old growing under a heavy overwood of blue pine were less than 2 ft. high. The case of the Nankhari Dhar plantation in Bashahr, referred to below, further illustrates this point ; indeed, wherever deodar reproduction exists plants in all degrees of suppression may be found under even a moderate canopy, many of them with tops bent over and flattened, exhibiting that stage of suppression at which they are past any possible aid by the admission of light. The important question of light will be alluded to again in dealing with the silvicultural treatment of the deodar.

6. *Miscellaneous factors.* Animals, birds, and insects which destroy deodar seed and seedlings have already been alluded to. Among these perhaps the worst enemies of natural reproduction are the insects, including cock-chafers and cutworms, which destroy young seedlings ; the damage done by them may be so extensive as to destroy all the seedlings over considerable areas. Much damage is sometimes done by hail, which strips the needles off young seedlings or cuts the seedlings in two, killing them in either case. Erosion by snow is the cause of absence of reproduction on the snow-slides so common in depressions running down the mountain sides at the higher elevations ; such places are the natural drainage channels for masses of snow, and as such are not suitable for tree-growth, although broad-leaved species sometimes make their appearance in such glades. The raking of litter, already alluded to, is the cause of a complete absence of natural reproduction in some of the forests of Kulu ; such areas, however, if closed to this practice, regenerate freely owing to the absence of raw humus. Grass-cutting is decidedly injurious, and accounts for the destruction of numerous seedlings.

In the majority of cases grazing is injurious to natural reproduction. Goat browsing in areas under regeneration is under no circumstances permissible, while the admission of buffaloes is incompatible with successful reproduction owing to the damage they do by trampling seedlings, injuring saplings, and hardening the soil where it is inclined to be stiff. Ordinary cattle grazing in strict moderation is less harmful, particularly where there is much shrubby growth, in which case it may even act beneficially in reducing cover which would otherwise suppress young deodar. In the great majority of cases, however, strict closure to all kinds of grazing is the safest course in areas under regeneration, and heavy grazing of any kind is inadmissible if only on account of the damage done by the trampling of seedlings. Some good examples of the adverse effects of unrestricted grazing on natural reproduction and the beneficial effect of strict closure are to be found in the forests of Kulu. Mr. Trevor quotes the following instances :

‘ In 1913 it was found in Nagri, Reunsigarh, and Marig that the seedlings growing in burnt patches were being destroyed by the feet of cattle ; they were at once excluded from Nagri, where the seedlings have been saved ; but the entire crop in Marig has been destroyed, and it has now been necessary to close the area to grazing. Similarly in Bohara, in which the burnt patches were sown in 1913, cattle have done a certain amount of damage in the portion not closed, and the growth of the plants in the fenced portion is 25 per cent. better than those outside. In the spring of 1913, when the experimental area in Bajraundi was closed and fenced, there were thousands of seedlings both inside and outside this area. Those inside still persist and are in a most flourish-

ing condition (1915), while outside under exactly similar conditions of soil and light nearly all have perished.'

Fire is a decidedly injurious factor where the natural reproduction of deodar has already been secured, since it may completely destroy the whole young crop, particularly in dry types of forest or where there is much inflammable undergrowth present. The spread of deodar reproduction into the region of *Pinus longifolia* as a result of the introduction of fire-protection has already been alluded to as illustrating the greater sensitiveness to fire of the deodar as compared with the pine. Fire, nevertheless, is an important agent in securing reproduction, which often fails unless measures are taken to burn felling refuse and troublesome undergrowth. As with most other conifers, so with deodar, natural reproduction sometimes appears in quantity as a direct result of a severe fire, owing to the admirable germinating bed formed by the ashes and to the removal of undergrowth. Mr. A. F. Broun¹ in 1886 recorded a case of abundant natural reproduction of deodar which had sprung up in the Kathiyan forest, Jaunsar, after a destructive fire caused in 1871 by villagers in order to propitiate their deity on an outbreak of small-pox. In 1886 there were still numerous dead blackened trees on the ground, while the natural reproduction of deodar was in many places very abundant; on a patch 10 ft. square 86 saplings, averaging 8 ft. in height, were counted, of which 62 were alive and 24 had been killed by suppression. The excellent pole crops now to be found in this forest are doubtless the result, in part, of the fire in question. In the working plan for the Dalhousie range forests, Chamba,² Mr. R. McIntosh, discussing the question of absence of deodar reproduction owing to heavy undergrowth, mentions that extensive conflagrations are said to have occurred many years previously at the time when the present mature crop had its origin, and that the introduction of fire-protection forty years prior to the time of writing synchronizes with the stoppage of extensive deodar reproduction. He thus surmises that the occurrence of periodic fires is not inconsistent with the regeneration of the deodar, and advocates that if grazing and cutting of undergrowth do not result in reproduction then the effect of repeated firing for a few consecutive years should be tried where reproduction fails.

ARTIFICIAL REPRODUCTION. *General considerations.* Deodar may be raised either by direct sowing of various kinds or by transplanting from the nursery. It may be noted that deodar has been successfully raised from cuttings in South Africa, though this method of propagation has not been resorted to in India. Sowing and transplanting from the nursery both have advantages, and both have been carried out with complete success in many localities. Direct sowings on a large scale, however, are not possible except in years when seed is tolerably plentiful, and hence, if artificial reproduction is to be carried out regularly on an extensive scale, it may be necessary to maintain a stock of nursery plants for transplanting purposes. There has sometimes been a tendency to employ methods of forming plantations which are so costly as to be quite unjustifiable; provided the cost is kept within reasonable limits, however, there is no reason why deodar plantations should not be made remunerative besides being culturally successful. Small isolated plantations are more

¹ Notes on Plantations and other Operations, 1886.

² Revised Working Plan for the Dalhousie Range Forests, 1913, paras. 16-20.

costly than those formed in extensive compact blocks, owing to the higher expenditure on the tending and upkeep of the former. The choice of site and the methods of formation to be adopted for different sites are of importance. Cases of failure are not infrequently due to attempts to grow deodar on ground unsuited to its favourable development, particularly on shallow rocky soil where the plants either die of drought when young or remain stunted if they survive.

In cool, damp situations, sowing and planting succeed best if carried out entirely in the open. On situations which are even moderately hot and dry, however, advantage should be taken of any shade that is available, though such cover should be removed as soon as the young plants are well established. In all but the coolest and dampest places seed should be sown, or seedlings planted, on the shady side of bushes, rocks, or clumps of grass. Shrubby growth should not be cleared more than is necessary, but only sufficiently to give sowing or planting room, light being given immediately overhead but side shade being retained. *Indigofera* and *Desmodium* are among the most useful shrubs under which to raise deodar; plantations are usually successful also in areas covered with *Parrotia Jacquemontiana*, though frequent cleaning is necessary to keep the *Parrotia* in check until the deodar is safe from suppression. Experiments in Jaunsar have shown that if *Indigofera* and *Desmodium* have to be introduced artificially they should be sown a few years in advance of the deodar in order that they may reach sufficient size to afford protection, since their growth at first is slow. Sowing or planting under the shelter of bushes can be most conveniently carried out along contour lines cleared through shrubby growth, the width of the clearing depending on the height and density of the shrubs and the degree of protection required; ordinarily clearing to a width of 2 to 4 ft. suffices.

Sowing and planting of deodar are not unattended by risks of various kinds. The dangers to which seedlings are exposed have already been referred to. Insects, particularly cockchafer and cutworms, often do extensive damage in sowings and in the nursery. Birds, including pheasants, devour the seed during the winter and the germinating seedlings during the spring, and where this form of damage is prevalent direct sowing may have to be discarded in favour of transplanting from the nursery, where protection can be afforded. The same applies in cases where monkeys have acquired the habit of pulling up young seedlings or where hail is specially destructive; in the latter case the young plants require to be protected in the nursery by screens. Plantations require careful protection from grazing, and where this cannot be effected otherwise, fencing is necessary, in which case the formation of plantations in compact blocks of fair size is essential in the interests of economy.

The success or otherwise of sowing and planting, and particularly the former, depends largely on the state of the season. Good results may be expected if the monsoon rains are timely and copious, or if sowings are followed by a heavy snowfall. Failing this there may be high mortality from drought. Tending operations in plantations are described on pp. 1023-4.

Mixtures. Some very successful deodar plantations have been formed under the shelter of tree nurses, of which the most important are blue pine and oak (*Quercus incana* and *Q. dilatata*). The nurses should be well opened

out or lopped before the deodar is introduced, and should not be retained longer than is necessary. Deodar has been successfully introduced in spruce forest in Kulu by means of horizontal line sowings, the spruce having first been opened out ; the spruce overwood, however, requires to be removed very early. The effect of introducing deodar artificially under blue pine can be studied in parts of Kulu, Bashahr, and Jaunsar. The results show that deodar can be introduced successfully under pine crops in the tree or pole stage, provided the overwood is well opened out first and is not kept over the young deodar crop longer than is necessary. Pole crops are more liable to cause suppression than crops of tall trees. The effect of leaving blue pine standing too long over a young deodar crop, as illustrated by the Nankhari plantation in Bashahr, is explained below under 'tending operations'. Another instructive plantation is that of Ramgarh Kundi in Kulu, situated at an elevation of 7,500 to 8,000 ft. on an isolated hill presenting varying aspects. Here in 1902 deodar was planted in pits spaced 10 ft. by 5 ft., and was also sown in lines, partly in the open and partly under a pole crop of blue pine previously opened out and lopped to some extent. In 1914, when the plantation was twelve years old, it was found that on every aspect except south and south-west the deodar planted in the open was far more vigorous than and about twice the height of that under the blue pine. On south and south-west aspects the results varied, though on the whole the deodar plants were most promising where protected by the side shade of young blue pine. In the open parts young blue pine was filling up gaps naturally in a most promising manner. In this plantation it would have been well to have removed the whole of the blue pine overwood within five years on all but the hottest aspects.

The best results in an artificial mixture of deodar with a natural crop of blue pine have been attained by sowing or planting the deodar in young sapling crops of pine a few feet high ; in such cases the two grow up together, the pine affording useful side shade to the deodar, and all that is necessary is to keep the deodar free from overhead suppression. Perhaps the greatest advantage to be gained by introducing deodar under a tree crop of blue pine is that the latter if well opened out regenerates naturally and fills up gaps, affording a useful mixture ; in such cases a wider spacing of the deodar plants suffices than would otherwise be the case. Under a young pole crop of blue pine, however, where natural reproduction of the pine is not anticipated, a pure deodar plantation must be allowed for. Figs. 451 and 452 show portions of the Jutli Kalwala deodar plantation in Kulu, fifteen years old, in which natural reproduction of blue pine, from seed-bearers in the neighbourhood, has appeared in great abundance, filling all gaps and growing up to form an ideal even-aged mixed crop with the deodar.

Direct sowing. In direct sowing the best results are attained by following Nature and sowing deodar seed in November and allowing it to lie through the winter, when it germinates early next spring. In case of failure, resowing may be carried out about April, and this occasionally gives good results. The chief disadvantages of spring sowing are that seed if stored for any length of time is liable to insect attacks, and that germination is usually delayed. Sowings may be carried out broadcast or in contour lines, broken or continuous, in patches of various sizes including elongated patches running along the



FIG. 450. Natural reproduction of deodar, with some blue pine and chir pine, establishing itself beneath an open overwood of chir pine as a result of fire-protection, Jaunsar, elevation 6,000 ft.



FIG. 451. General view over portion of Jutli Kalwala plantation, Kulu, 15 years old, showing mixture of deodar with *Pinus excelsa*, which has appeared naturally and is filling up gaps.



FIG. 452. Deodar plantation, 15 years old, in which *Pinus excelsa* has regenerated naturally in abundance, Juthi Kalwala, Kulu.



FIG. 453 Deodar forest, showing tendency for natural reproduction to spring up in groups where there are gaps in the canopy, Jaunsar.

contour, or by dibbling. Where line, patch, or broadcast sowing is adopted, thorough preparation of the soil is necessary by hoeing to a depth of several inches, preferably after collecting and burning all refuse. After sowing the seed should be lightly covered with earth.

Broadcast sowings over large areas are somewhat expensive, but they are particularly useful in sowing up abandoned cultivation and gaps where felling refuse has been collected and burnt. The quantity of seed required per acre actually sown is about 20 to 25 lb. Where much weeding is anticipated, or where the sowings have to be carried out in areas covered with shrubs and other growth, contour line sowings are the most suitable. A distance of 10 ft. between lines has been found by experience to give good results. If the distance is greater the crowns do not meet in time to prevent the formation of strong branches. The lines should be made in the form of terraces 1 ft. wide, well hoed up, one line of seed being sown along the centre of the terrace; 20 lb. of seed suffices for one acre. Weeding along contour line sowings is easy, but such sowings are particularly liable to the attacks of insects and other pests, and if grazing animals gain access they use the contour terraces as paths and do much damage. Sowings in hoed patches varying in size from 1 ft. square upwards are simple and cheap, but are unsuitable where weed-growth is heavy. They are useful for filling gaps in young crops of blue pine 2 or 3 ft. high. Great success has been attained in Kulu by sowing in patches in gaps where felling refuse has been thoroughly burnt. The seed is stirred up in the patches of ashes, and the resulting seedlings show rapid growth. The patches are used next year as temporary nurseries, surplus seedlings being planted throughout the gap during the rainy season. The thinning out of seedlings in line and patch sowings is a very necessary operation. Excess plants should be employed as far as possible for filling up gaps, after which the remainder should be thinned out with a pruning knife not later than the third year, failing which the plants become congested and weakly. Dibbling should be carried out only in loose soil; it is useful for introducing deodar in young blue pine crops.

Planting. The nursery treatment of the deodar presents no special difficulty. The nursery should be free from overhead shade, though side shade is an advantage on hot aspects. The seed-beds, about 4 ft. wide, composed of light, porous soil preferably with an admixture of leaf-mould and wood-ashes, should be well hoed up and raised. The seed should be sown in November, soon after collection, in drills 4 to 6 in. apart, and the beds should be covered with thorny twigs to keep off birds, the twigs being removed when germination begins. Germination takes place early next spring, and in hot situations or where hail is to be feared the seed-beds should be protected by light shades until the rainy season. Watering, which should be carried out sparingly, is not as a rule necessary except in May and June; regular weeding, however, is advisable. It is usually customary to prick the seedlings out in the nursery in July of the year of germination with a spacing of 6 in. by 4 in., and again in July of the second year with a spacing of 9 in. by 6 in., finally planting them out in July of the third year, after the rains have well set in, by which time they are 12 to 18 in. high. The less vigorous plants may be pricked out again and planted out in the fourth year. In Kulu planting is carried out the

year after sowing, with seedlings averaging 8 in. high ; these are transplanted direct from the seed-beds without any pricking out in the nursery. By this method much expense is saved and the results are quite successful.

During the transfer of seedlings from the nursery to the planting site the roots should never be exposed to the sun. Cloudy or rainy weather should be selected if possible, and the seedlings should be packed in bundles with wet moss round the roots, placed in a basket, and carried thus to the planting site. Planting, which commences as soon as the rainy season has well set in, should be pushed on rapidly in order to obtain the full benefit of the rains. Winter transplanting has been tried in different localities with variable results, the success depending a good deal on the snowfall. In regions beyond the reach of the monsoon, winter planting has to be resorted to as a matter of course. Deep wide planting holes are unnecessarily expensive ; provided they are large enough to admit the roots freely, this is sufficient. Unnecessary width in particular should be avoided, since there is a danger of the plants becoming loosened by heavy rain where the holes are too wide. The earth filled into the holes should be well pressed down, care being taken not to sink the plant below its original level. On hot aspects advantage should be taken, in planting, of the shade afforded by bushes, rocks, or tufts of grass. In the case of basket planting the seedlings are pricked out in the nursery during the first rains, transferred to baskets during the second rains and planted out with the baskets in the following year. These baskets, which are made of ringal bamboo, are 4 to 6 in. in diameter and 8 or 9 in. long, and in Jaunsar cost Rs. 1-8-0 to Rs. 2-8-0 per 100. Their use adds very materially to the cost of the plantation, and cannot be justified where less expensive methods can be employed ; basket planting, however, usually results in a high percentage of success.

The most usual spacing for deodar is 5 ft. by 5 ft., or in the case of contour lines, 3 or 4 ft. apart in lines 8 to 10 ft. apart. Spacings of 4 ft. by 4 ft. or 6 ft. by 6 ft. have also been employed to some extent. The former produces very dense crops with clean stems, but is perhaps unnecessarily close, since a spacing of 5 ft. by 5 ft., if the plantation is successful, gives all the density required. Where deodar is to be planted in an area being regenerated naturally for blue pine with the view of obtaining a mixed crop, a spacing of 10 ft. by 5 ft. is ample. Planting in cleared contour lines is the most satisfactory method to adopt where the growth of shrubs and weeds is heavy, since weeding is greatly facilitated.

Cost of sowing and planting. The actual cost of sowing and planting in different localities has varied greatly. Planting, including all nursery charges and transplanting, should not exceed Rs. 20 per acre, and in the Nogli range of Bashahr the average for some years was as low as Rs. 9 per acre. Under the system now followed in Kulu, in which seedlings are not pricked out in the nursery but are planted out the year after germination, the planting holes being no larger than is necessary, the cost works out at Rs. 4 to Rs. 5 per acre for a spacing of 5 ft. by 5 ft. The cost of basket planting in Jaunsar has averaged about Rs. 60 per acre with a spacing of 5 ft. by 5 ft., excluding the cost of subsequent tending. Broadcast sowing in Bashahr, though successful, has proved somewhat expensive, the cost of digging being Rs. 20, and of



FIG. 454. Natural reproduction of deodar in a blank round a seed-bearer, Jaunsar.



FIG. 455. Result of seeding felling in deodar forest ; area fully regenerated with a young natural crop of deodar and blue pine, now ready for final felling ; Kulu.



FIG. 453. Group of young deodar poles about 30 ft. high sprung from a seed-bearer recently removed, leaving a blank (in foreground). seed-bearer should have been removed many years previously. Jaunsar.



FIG. 457. Natural reproduction of deodar and blue pine, with a little spruce, resulting from an even spacing of seed-bearers 20 per acre - young crop chiefly 5-8 ft. high and ready for freeing completely from overhead cover; Bashahr.

sowing Rs. 5 per acre. Direct sowing in lines or patches should not exceed Rs. 10 per acre, and patch sowing can be done for Rs. 3 per acre or less. In Kulu sowing in prepared contour lines 10 ft. apart costs Rs. 10 per acre, including the preparation of terraces and sowing, or Rs. 16 to Rs. 20 per acre, including subsequent weeding, cleaning, and early thinning. In the same division heaping and burning felling refuse, sowing up the burnt patches, transplanting surplus plants from the patches and subsequent weeding, resulting in the complete regeneration of the area operated over, costs on an average Rs. 10 per acre. The cost of weeding and cleaning varies greatly with the extent of the weed-growth. As a general rule these tending operations up to about the fifteenth year cost about Rs. 8 to Rs. 15 per acre, though the cost may be less where weed-growth is not heavy.

SILVICULTURAL TREATMENT. The treatment of the deodar may be conveniently considered under three separate heads : (1) regenerative measures, (2) tending operations, and (3) silvicultural systems.

1. *Regenerative measures.* The chief factors, so far as they are known, which bear on the natural reproduction of the deodar have already been considered. Where conditions are favourable the natural tendency of the deodar is to regenerate in groups or masses of more or less even age in the neighbourhood of seed-bearers, either in gaps of sufficient size or in completely isolated situations. Fig. 453 shows a typical instance of a group of reproduction springing up in a gap. Where, as is often the case under the present condition of the forests, the old crop consists of somewhat scattered branchy deodar trees, often of considerable size, this tendency, which is illustrated in successive stages in Figs. 454 and 456, is very marked ; these two photographs were taken in the same locality. In such cases reproduction first appears partly underneath the tree and partly in a fringe of varying breadth extending for a distance often of many yards round it, particularly on the downhill side. As the young crop grows the seedlings beneath the spreading branches of the seed-bearer become killed off, partly by suppression, and partly perhaps because they get little rain and snow, and a complete blank results beneath the tree. In Fig. 454 this stage is commencing, while in Fig. 456 the blank beneath the seed-bearer, recently removed, is complete, and in the fringe of reproduction round it the dominant stems have reached a height of 30 ft.

Regeneration in small groups, patches, or fringes arising in gaps or round isolated seed-bearers has had to be relied on to a considerable extent in the past, and in the open condition of so many of the existing deodar crops it will play a prominent part for some time to come. Crops which originate in this way, however, are far less satisfactory than crops of even age extending over considerable areas, for whereas the latter produce clean straight timber, small groups of trees standing alone produce strong branches and knotty timber. The same applies to solitary seedlings or small patches of seedlings, which often appear under other species such as oak or blue pine considerably older than themselves, and eventually establish themselves in gaps. Such isolated plants develop into branchy trees. The ideal, therefore, should be to aim at producing even-aged crops of considerable density over as large an area as possible, affording complete overhead light as soon as the seedlings are safe from the desiccating effects of the sun. Fig. 445 shows an even-aged pure

pole crop which has originated from a mass of even-aged natural reproduction of some extent, and the clean appearance of the stems may be compared with the branchy appearance of those which are produced by the small group shown in Fig. 456. The details of the crop shown in Fig. 445 are as follows : age, 45 years ; mean height, 61 ft. ; mean girth, 34 in. ; stems per acre, 517 ; volume per acre, 7,929 cubic ft., of which 6,049 cubic ft. is timber down to 24 in. in girth. It is clear that in order to take advantage of natural reproduction appearing in small groups and at the same time to link these groups together into an even-aged crop, no undue delay should occur in removing seed-bearers which have already done their work and in completing the stocking of the area artificially if necessary. In Fig. 454 the young crop has already reached the stage at which it should be freed from the seed-bearer, any resulting blank being filled up artificially.

Dense even-aged pure crops of deodar, such as that shown in Fig. 445, are common in many localities, and are as well represented in Kulu as anywhere. Many of them have doubtless arisen with the introduction of fire-protection in areas previously subject to frequent fires, and some at least have arisen on abandoned cultivation (Fig. 446). Such crops not only produce better and cleaner timber than that produced by small groups of trees or uneven-aged crops, but they lend themselves more satisfactorily to thinnings and other tending operations. Provided the crops are more or less even aged, however, it is not necessarily advisable that they should be pure. Excellent results are obtained by the regeneration of deodar in even-aged mixed crops with blue pine or spruce. A mixture of deodar with oak is likewise a good one, but as the deodar grows much more rapidly than the oak the deodar crop should be sufficiently dense to clean itself after it has overtopped the oak, or should have a sufficient quantity of blue pine or spruce mixed with it to produce a completely stocked crop. As is the case with other conifers, deodar often regenerates with great freedom beneath the oak, the soil conditions being particularly favourable, and where the cover of the oak is light, as in places where it is subject to lopping, deodar crops of considerable density may make their way through the oak. Cases may sometimes be observed where in oak forest subject to lopping a deodar crop is slowly but surely taking the place of the oak. Deodar likewise regenerates well beneath the light shade of the blue pine, and provided the latter is removed in good time the deodar establishes itself without difficulty. It happens frequently that isolated deodar plants establish themselves in this way, and are duly freed in cleaning operations by the removal of large blue pine trees standing over them ; such operations are not as a rule to be commended, for at the best the isolated deodar plants, unless there is a sufficiency of other young growth with them to produce a fairly dense crop, can only produce branchy trees.

Granted that the ideal is to secure even-aged regeneration, whether in pure or in mixed crops, this ideal is not always easy of attainment, since a combination of factors favourable to reproduction is not always present. This is due to some extent to the state of so many of the existing mature crops of deodar, which have grown up in an open and irregular condition, with the result that there is often a matted growth of grass or a dense growth of weeds on the ground, or the soil has become hardened by excessive grazing. Completely

stocked even-aged crops approaching maturity are not at present available in sufficient number to study the effect, under different conditions, of an even opening out of the canopy by a definite spacing of selected seed-bearers. Judging by such instances as are available, however, there is every indication that one of the best methods of regenerating deodar crops, where conditions lend themselves to it, will be by an even spacing of seed-bearers in seeding fellings—the actual spacing depending on the radius of seeding and the degree of protection required—followed by the final removal of the overwood in one or more fellings as soon as regeneration has been secured and protection for the young crop is no longer required. The selection of cone-bearing trees with well-developed but not too spreading crowns will be an important consideration in the execution of the seeding fellings.

A few instances may be quoted of the observed results of an even spacing of seed-bearers. In 1911 a dense pure pole crop of deodar, in which the trees averaged less than 3 ft. in girth, was observed in which numerous small gaps were made in the canopy by snow-break which occurred a few years previously, resulting in places in a more or less even opening of the canopy, the gaps varying from about 5 to 10 yds. wide from crown to crown. The result was the appearance in every gap of large numbers of seedlings, which at the time of observation were four years old, and could have been freed with perfect safety. This example indicates that even in pole crops the opening of the canopy by even spacing may result in the complete regeneration of the area in one good seed-year. Better examples of dense young even-aged crops of deodar, sometimes pure, sometimes mixed with *Pinus excelsa* and *P. longifolia*, under an open canopy, could hardly be obtained than in the case, already quoted, of the ingress of deodar into the region of *P. longifolia* as a result of fire-protection in areas previously burnt (see Fig. 450).

Some of the best examples of even-aged natural reproduction of deodar obtained by a more or less uniform spacing of the canopy are to be found in mixed forest of deodar and blue pine, with or without spruce. In Kulu, where Mr. Trevor has done much experimental work in the regeneration of the deodar, are to be found some good examples of successful reproduction, both in pure deodar crops and in mixed crops of deodar and blue pine, obtained by an even opening of the canopy. Fig. 455 shows in the background a crop opened out in a seeding felling, with natural reproduction making its appearance, and in the foreground a regenerated crop with the removal of the overwood almost completed. Reproduction in this coupe was probably favoured by the regular removal of litter prior to the commencement of regeneration fellings, when this practice was prohibited; closure to grazing is here found to be essential to the establishment of reproduction. In this locality a spacing of the mother trees of 30 to 50 ft., giving about 17 to 48 trees per acre, is found to be suitable in seeding fellings. The actual spacing of seed-bearers must vary considerably according to circumstances; thus on hot aspects a closer spacing is required than on cool aspects, while caution is necessary in opening the canopy where a heavy growth of weeds is feared. Figs. 411, 457, and 458 show excellent reproduction of deodar mixed with blue pine and a little spruce obtained with a spacing of seed-bearers to 5 or 6, 20 and 10 per acre respectively. In such cases the overwood should be removed

rapidly after reproduction has appeared, and its final removal should be effected by the time the young crop is five to ten years old.

In the instances just quoted the conditions for obtaining natural reproduction have not been unfavourable, and reproduction has been effected without any other measures than opening the canopy sufficiently and closing to grazing and the removal of litter. In many cases, however, reproduction cannot be obtained so easily owing to unfavourable conditions of soil and soil-covering. Here Mr. Trevor's experiments in Kulu have shown that regeneration can be effected with complete success, after fellings have been completed, by collecting and heaping the felling refuse in gaps, at the same time cutting and heaping undergrowth where necessary, and burning the whole thoroughly. The collection of refuse into heaps without burning, in order to clear the ground for the reception of seed, has been tried without success; the essential operation is the burning, which results in an excellent germinating bed and the thorough clearing and enrichment of the soil. It will be of interest to describe briefly the methods employed with success in Kulu. The collection and burning of refuse should be carried out soon after the forest has been exploited, preferably in a good seed-year and before the seed has fallen. The burning of refuse can be carried out with safety to the surrounding crop only if gaps of fair size are created. The refuse, consisting of felling débris and cut undergrowth, is collected in the centre of these gaps away from trees or advance growth; special iron rakes have been found useful for collecting the smaller chips of wood. The heaps should be as large as possible, the small chips, which do not burn well by themselves, being mixed with the larger pieces. As a rule the heaps should be fired in the evening and allowed to burn all night. The burning is best carried out during or immediately after the rainy season, in order to avoid risk of firing the forest; in damp forest, however, it is better to burn in the spring. Burning should begin at the top of the slope, otherwise the ascending smoke renders work difficult on the uphill side. Where the refuse has not been completely consumed by one burning it is collected and burnt again, and after complete burning has been effected the ashes are scattered if necessary over the gap. The cost of collecting and burning refuse averages Rs. 1-8-0 per acre, but in some forests in Kulu the work is done free of charge by villagers in return for grants of unsaleable material which is cut in opening out the crop, and which would otherwise be burnt. After the burning has been completed the area appears as if a severe ground fire had passed over it, and in place of a mass of wood chips, tops, and branches, which prevent reproduction, an excellent soft germinating bed of wood-ashes is produced, in which seedlings grow with abnormal vigour. Fig. 459 shows a gap in which the collection and burning of refuse has just been completed. Where the number of seed-bearers is insufficient, or when the seed-year is a poor one, these burnt gaps are sown broadcast at a cost which averages 1 anna 8 pies per acre. This system of collecting and burning refuse, followed by sowing, has proved successful in effecting complete regeneration in areas which had long defied all attempts to obtain it.

Hoeing the ground in the vicinity of seed-bearers has been found to give very variable results in different localities, but the conditions under which

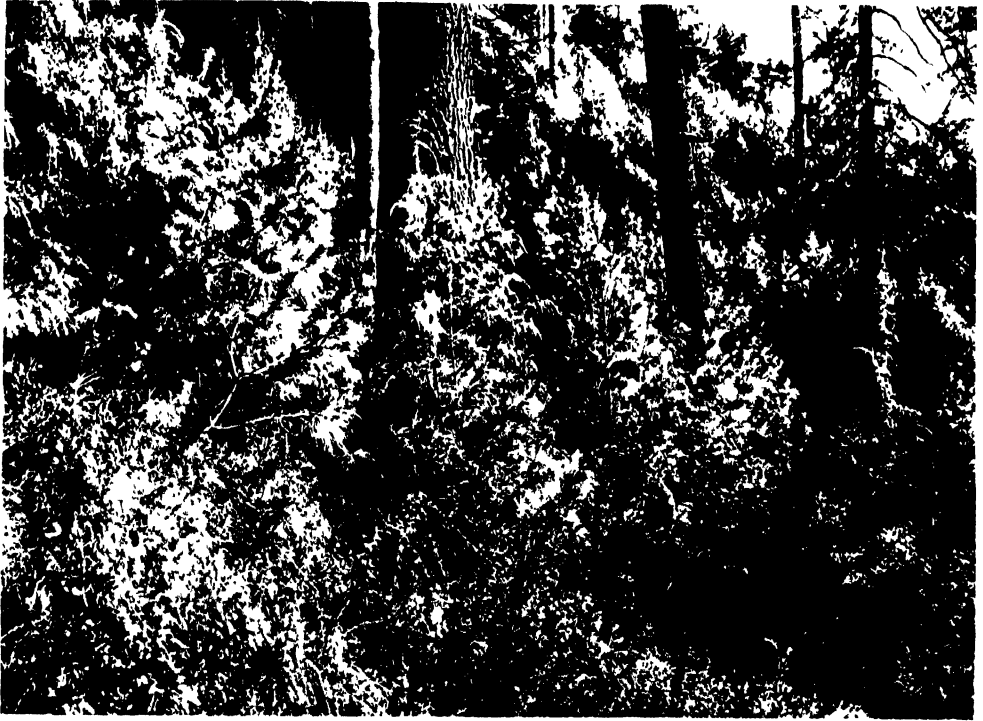


FIG. 458. Natural reproduction of deodar and blue pine, with a little spruce, resulting from an even spacing of seed-bearers, 10 per acre ; young crop well established and in need of freeing from overhead cover ; Bashahr.

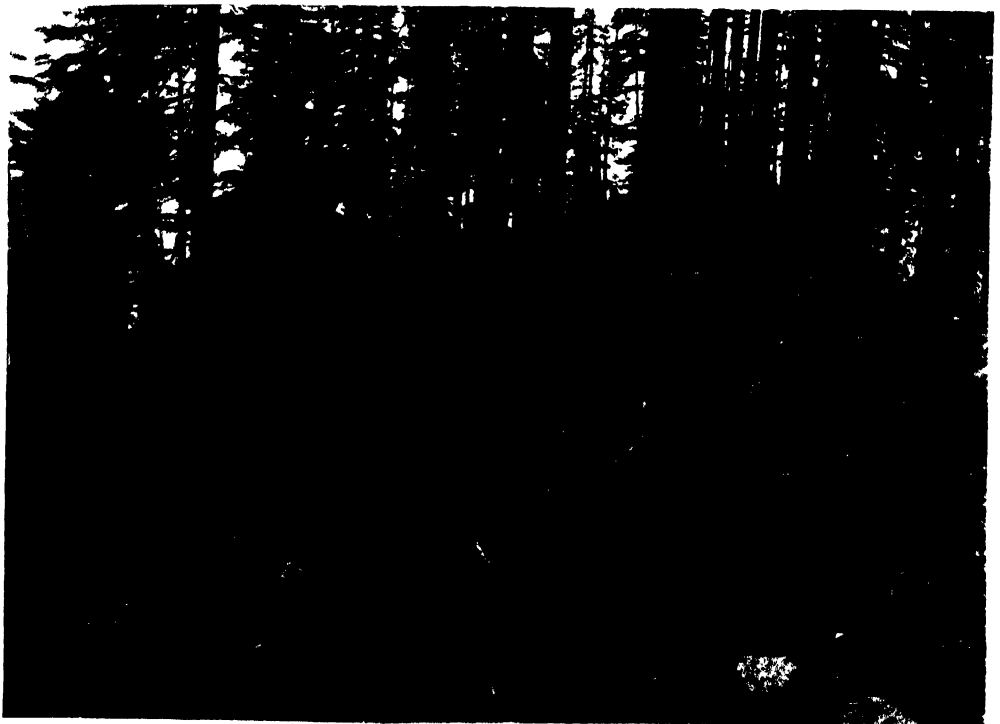


FIG. 459. Deodar forest opened out for regeneration, and burning of refuse completed, Kulu.



FIG. 460. Tending operations in young deciduous crops : oak and rhododendron girdled

the work has been carried out have not been recorded in sufficient detail to draw definite conclusions. In an experiment at Taprog in Bashahr it was found that thorough hoeing in the autumn in a good seed-year, before the fall of the seed, produced a plentiful crop of natural reproduction. In this case the seed was found to fall in sufficient quantity to a distance of 200 ft. on the downhill side of the seed-bearers.

The value of side shade as a protection against desiccation is now well understood in European forestry, and the question of utilizing it on hot aspects deserves further study in connexion with the establishment of deodar reproduction. Various cases have been observed in which reproduction springs up in masses where it receives side shade from the sun, but this does not always happen, and the direction from which side shade is most beneficial under different conditions remains to be determined. In Jaunsar cases of profuse reproduction on hot southerly aspects have been observed where side shade was afforded from the south-east, and here the morning sun would appear to be the unfavourable factor. In gap fellings in Chamba, where the openings are sufficiently large, the best reproduction is found round the edges of the gaps, not immediately under the surrounding trees, but at some little distance from them, while in the centre of the gaps the seedlings tend to die from drought. In Kulu, however, the most vigorous saplings are usually found in the centre of a gap, and not round its edges ; this indicates that side shade may not be beneficial under all conditions.

2. *Tending operations.* In young deodar crops, whether natural or artificial, tending operations begin with the weeding of rank herbaceous growth and undershrubs ; this is particularly necessary in direct sowings. Where weed-growth is heavy, two weedings in the first year are usually required, one in June and the other in August, but where the weeds are not luxuriant a single weeding in August suffices. Where weeds are plentiful, weeding may have to be continued for three or four years. In hot situations the removal of shrubs requires to be carried out with caution, for although the freeing of the leaders of the young plants is always desirable, the removal of weeds, and particularly of shrubs, to the extent of exposing the soil to desiccation, should be avoided. Hoeing the soil round young plants during weeding is dangerous if snow is prevalent, since this increases the risk of their being bent down by snow. A subsequent and most important operation is that of freeing young deodar saplings from the overhead cover of other trees beneath which they are growing, of which the most important are probably blue pine and oak. This operation is variously termed a cleaning or an improvement felling ; in carrying it out the important points to remember are that the sooner full overhead light can be safely admitted and the leader completely freed the better, while on the other hand side shade should be retained as far as possible, since isolation produces branchy trees. Some of the most promising young deodar crops are to be found in places where the systematic lopping of blue pine or oak is carried out, and where natural reproduction of deodar has appeared under the lopped overwood ; the lopped trees tend to form a bushy growth, affording side shade with plentiful gaps overhead, and the young deodar crop profits greatly by these conditions.

In actual practice it is often the custom, instead of felling the trees whose

removal is desired, to kill them by girdling, in order to save the expense of felling. Lopping or topping these trees in place of felling or girdling them is usually preferable wherever this can be done conveniently, since it frees the leaders of the deodar while tending to prevent the development of side branches. Fig. 460 illustrates the freeing of natural deodar saplings by the girdling of oak.

The Nankhari plantation in Bashahr affords some instructive lessons in the removal of blue pine over a young deodar crop artificially introduced under it. The elevation is between 7,000 and 7,500 ft., and the aspect is mainly east; the plantation was formed chiefly between 1904 and 1907 by sowing and planting deodar under an overwood of blue pine. The results have shown that the deodar is more liable to suppression under a pole crop than under a crop of tall trees, and that in either case the total clearance of the overwood should be effected within a few years of introducing the deodar. This plantation was visited in 1914, when it was seven to ten years old, and it was found that the deodar crop was vigorous only in large gaps where the pine had been completely cleared, and that where the overwood was at all dense the young crop had become suppressed or exterminated. Figs. 461, 462, and 463 give some idea of the condition of the young deodar crop under various degrees of overhead cover.

Cleanings should be repeated at frequent intervals, particularly where blue pine is concerned, since this tree outgrows the deodar in its earlier stages. The freeing of badly suppressed deodar plants which have become flat-topped and bent over is a useless operation, since plants which have reached this stage do not respond to the admission of light.

Thinnings are a very necessary operation in deodar crops. These should begin early and be repeated at intervals of not more than ten years; among other advantages the gradual opening of the crop in this way is the surest safeguard against damage by snow. A system of thinning young deodar thickets by the agency of forest guards, which was devised by Mr. Trevor in Kulu, has been found to work well in practice. A stick, the length of which varies with the average spacing required, is employed to measure the distance between stems; when held horizontally, as long as it passes between two adjacent saplings, nothing is removed, but if it does not the worse specimen is felled and the better one retained. It has been found that if a stick 4 ft. long is employed an average spacing of 6 ft. is obtained. By this means large areas of congested sapling crops are operated over which could not otherwise be dealt with satisfactorily.

Subsequent thinnings are carried out on recognized silvicultural lines. They include the removal of inferior species and of deodar stems which are snow-broken, attacked by *Peridermium Cedri*, misshapen, and otherwise undesirable. Owing to the tendency of the deodar to produce strong branches in open crops, care should be taken not to break the canopy severely, but to thin sufficiently to cause the crowns to touch and no more. The last thinning should be in the form of a preparatory felling to stimulate crown development and seed production. Improvement fellings in the shape of the removal or girdling of spruce, silver fir, blue pine, oak, and other trees which are interfering with promising deodar are regularly carried out in many of the existing forests. These fellings, if intelligently carried out, are most useful, but the



FIG. 461. Plantation of deodar 7-10 years old under pole crop of blue pine, Nankhari, Bashahr (1) blue pine, insufficiently opened out, and deodar, where not already killed by suppression, only 2 to 4 ft. high and becoming suppressed.



FIG. 462. Plantation of deodar 7-10 years old, under pole crop of blue pine, Nankhari, Bashahr (2) young deodar completely freed in large gap in pine crop, but suppressed in foreground where cover is denser.



FIG. 463. Plantation of deodar 7-10 years old, under pole crop of blue pine, Nankhar, Bashahr.
(3) deodar crop completely freed at an early stage, in vigorous condition, 7-10 ft. high, with young blue pine filling up gaps naturally.



FIG. 464. *Abies Pindrow* forest at 9,500 ft., with some *Quercus semecarpifolia*, Kulu.

wholesale removal of trees of prospective value in the interests of small isolated and often suppressed or branchy deodar trees cannot be justified.

3. *Silvicultural systems.* The treatment adopted generally for the deodar forests at the time when attempts were made to introduce systematic working where no system had previously been in force, was that of selection fellings under a definite felling cycle, and with a minimum exploitable girth or diameter for sound trees ; the opportunity was also taken to carry out improvement fellings with the object of removing unsound or badly shaped deodar as well as accessory species interfering with promising deodar stems. As a means of improving the existing crop this treatment has had beneficial results, but here its utility has ended. Experience everywhere has shown that the selection system has failed both to effect reproduction to the extent desirable or to bring the forests into a more normal condition, and this is not surprising considering the light-demanding character of the tree and the necessity for paying special attention to regenerative operations. The tendency of the deodar to regenerate in groups, where gaps of sufficient size are created, led in some cases to the prescription that the trees should be felled not singly, but as far as possible in small groups with the object of creating gaps. This takes into account the silvicultural requirements of the species to some extent, but the diffusion of work has rendered it impossible in practice to pay sufficient attention to regenerative measures in each gap. Natural reproduction, if it happens to appear at all, stands a strong chance of disappearing through suppression, for it is impossible to attend systematically to large numbers of small gaps scattered over extensive stretches of mountainous country ; in many cases, again, nothing but a heavy growth of weeds appears in the gaps. This uncertainty in obtaining reproduction can hardly be held to warrant the sacrifice involved in felling undersized trees with the object of creating gaps, while apart from silvicultural considerations, concentration as apart from diffusion of working is of special significance in difficult country where it may be necessary to construct export works.

The need for concentration accordingly led some years ago to the proposal that the group system should be applied to all the important deodar forests of the Punjab ; fortunately this proposal was not acted on, for the rigidity with which it was proposed to apply it would have foredoomed it to failure. A working plan prescribing the group system was actually framed in 1911 for the Upper Ravi forests of Chamba, but so far the results attained have not been altogether satisfactory, natural reproduction often failing from one cause or another. Although it is too soon to form a definite opinion as to the results of the group system in Chamba, it seems doubtful if the adoption of this system in itself is likely to lead to successful results, for it would be impossible under Indian conditions to apply it with the detailed attention with which it is applied in Europe, and as a system it is somewhat complicated.

There can be no doubt that in the future treatment of the deodar forests, concentration of working and of regenerative and tending operations must form the basis of successful management. The details of treatment will vary with local conditions. The freeing of promising advance growth by the creation of gaps will no doubt form an important item in the fellings, but this should be combined with the uniform opening of the canopy in the form of seeding fellings with the object of creating even-aged young crops wherever conditions

lend themselves to this treatment. On hot aspects there may yet be scope for the adoption of fellings in strips against the sun, with the object of securing the advantages of side shade. In general, however, the successful establishment of the young crop will depend largely on the amount of detailed attention given to regenerative and tending operations such as those described above, and provided these are carried out over definite manageable areas a fair degree of success should be attained. It is not advisable to prescribe any rigid form of fellings such as group, strip, or uniform fellings; a study of the ground and the crop will generally indicate how the fellings should be carried out. Natural reproduction will almost certainly require to be supplemented by artificial reproduction, but care should be taken not to attempt to stock ground which Nature never intended to support a crop of deodar.

A working plan on the elastic lines just indicated has recently been prepared by Mr. Trevor for the deodar forests of Kulu. The rotation is fixed at 120 years, and is divided into four periods of thirty years each. The regeneration fellings in any year may be carried out in any part of periodic block I; their number and periodicity, and the method of executing them, are not rigidly laid down. After the first regeneration felling all refuse, bushes, inferior trees, raw humus, and suppressed advance growth will be collected and burnt, and the soil will be brought into a suitable condition to receive the seed, if necessary by hoeing. All low spreading branches will be pruned off the mother trees in order to admit light and rain to the ground. The yield is fixed by volume.

STATISTICAL. *Thickness of bark and sapwood.* The following table, based on 250 measurements made in Jaunsar, gives the average thickness of bark in that locality:

Cedrus Deodara: bark thickness, Jaunsar.

Girth of tree over bark.	Bark thickness.	Girth allowance for bark.	Girth of tree over bark.	Bark thickness.	Girth allowance for bark.
	in.	in.		in.	in.
1 ft. and under	0.2	1.3	5 ft. 1 in.-6 ft.	0.7	4.4
1 ft. 1 in.-2 ft.	0.3	1.9	6 ft. 1 in.-7 ft.	0.9	5.7
2 ft. 1 in.-3 ft.	0.4	2.5	7 ft. 1 in.-8 ft.	1.0	6.3
3 ft. 1 in.-4 ft.	0.5	3.1	8 ft. 1 in.-9 ft.	1.1	6.9
4 ft. 1 in.-5 ft.	0.6	3.8	Over 9 ft.	1.2	7.5

As regards sap-wood, there does not appear to be any very definite relationship between the size and age of the tree and the thickness of sap-wood, the latter varying considerably for trees of the same size and age, particularly in the case of small trees. An average of 220 measurements in Kulu and Jaunsar gave the following results:

Cedrus Deodara: measurements of sap-wood.

Girth of stump over bark.	Corresponding radius without bark.	Thickness of sap-wood.		
ft.	in.	Minimum.	Maximum.	Mean.
1-4	1.7-7.1	1.2	3.0	1.6
4-6	7.1-10.8	1.3	2.2	1.7
6-12	10.8-21.8	1.5	2.8	2.2

This shows a somewhat greater thickness of sap-wood for the larger sized trees, but as the number of measurements on stumps under 6 ft. in girth was considerably less than in the case of larger stumps it is possible that the figures for the former do not represent very correct averages.

Rate of growth in young plantations. Measurements in 33 plantations in Jaunsar showed the following average :

Age (from seed).	Mean girth.	Mean height.
years.	in.	ft.
10	2	4
15	6	9
20	..	15
25	..	23

Individual plantations showed great variation in the rate of growth. Many of these plantations, again, were formed on somewhat unfavourable sites and were not regularly tended ; the growth therefore is slower than what might be expected under more favourable conditions. The Kawaragarh plantation in Kulu, formed by line sowings, had a maximum girth and height of 2 ft. and 25 ft. when seventeen years old. The Bindraban plantation, also in Kulu, had a mean girth of 10–12 in. and a mean height of 45–50 ft. when thirty-two years old.

Girth increment. The statement opposite has been compiled from measurements recorded for the most part in working plans. These measurements are recorded in different ways, some by girth and some by diameter, some inclusive and some exclusive of bark ; in some working plans a number of years are added to the age to allow for the time a seedling takes to establish itself, while in others no such addition is made. In order to place all the results on the same footing all measurements have been converted to girth over bark, and no allowance has been made for the time required for the seedling to establish itself ; this period is usually taken at ten years, and this or some other suitable period should be added to the age in each case if the measurements are to be applied in practice.

General quality classes. The table below shows a tentative allotment to general quality classes according to height-growth, based on 83 separate measurements of even-aged fully stocked sample plots laid out by the Forest Research Institute in Jaunsar, Bashahr, Kulu, and Chamba. This allotment may be regarded for the present as merely provisional, pending the collection of more exhaustive data.

Cedrus Deodara : allotment to quality classes according to height-growth

Age.	I quality.	Height.	II quality.	III quality.
years.				
20	21 feet and over	9 feet to	21 feet	Under 9 feet
30	36 " "	17 " "	36 " "	" 17 "
40	50 " "	26 " "	50 " "	" 26 "
50	65 " "	36 " "	65 " "	" 36 "
60	78 " "	46 " "	78 " "	" 46 "
70	90 " "	55 " "	90 " "	" 55 "
80	101 " "	65 " "	101 " "	" 65 "
90	111 " "	74 " "	111 " "	" 74 "
100	120 " "	83 " "	120 " "	" 83 "
110	126 " "	89 " "	126 " "	" 89 "
120	131 " "	93 " "	131 " "	" 93 "
130	134 " "	96 " "	134 " "	" 96 "
140	137 " "	97½ " "	137 " "	" 97½ "
150	138 " "	98½ " "	138 " "	" 98½ "
160	139 " "	99 " "	139 " "	" 99 "
170	139½ " "	99½ " "	139½ " "	" 99½ "
180	140 " "	99½ " "	140 " "	" 99½ "
190	140 " "	100 " "	140 " "	" 100 "
200	140 " "	100 " "	140 " "	" 100 "

Form factors. The following table of timber form factors has been prepared tentatively for trees growing in even-aged fully stocked crops of I and II qualities :

Cedrus Deodara : timber form factors for trees in I and II quality crops.

Height. ft.	Form factor.	Height. ft.	Form factor.
41-50	0.17	81-90	0.34
51-60	0.23	91-130	0.36
61-70	0.29	131 and over	0.35
71-80	0.32	..	..

These form factors have been obtained from the formula $f = \frac{v}{sh}$, where

f = form factor.

v = solid volume of timber in the round (excluding bark) down to a girth (measured over bark) of 2 ft. ; volume calculated from quarter-girth-squared measurement.

s = sectional area at $4\frac{1}{2}$ ft. from ground-level.

h = total height of tree.

Statistical results obtained from measurements in Research Institute sample plots. The table opposite summarizes the results obtained so far from measurements made in even-aged fully stocked sample plots laid out by the Forest Research Institute in Jaunsar, Bashahr, Kulu, and Chamba. These results may be regarded as purely tentative and only roughly approximate, since the data at present available are insufficient for the compilation of accurate statistics. The quality classes adopted are those quoted above ; statistics are at present insufficient to warrant the preparation of volume figures for crops of quality III or to enable estimates of intermediate yields to be formed for crops of any quality.

Local out-turn statistics. Extensive measurements have been made for many years past in different localities with the view of preparing out-turn statistics of felled trees of various sizes. The trees felled grew under varying conditions in untended and usually irregular crops ; many of the trees, having grown in open positions, were branchy, while some were over-mature and unsound. Figures deduced from these measurements, therefore, although applicable locally in respect of trees growing under past conditions, mainly in irregular crops, cannot be taken as typical of trees grown in even-aged, tended, normal crops such as will be produced in future under scientific treatment. Some of the results of these measurements may be quoted.

Hazara. The following statement (p. 1130) has been compiled from out-turn figures based on 1,518 measurements recorded by Mr. A. V. Monro in the Kagan range working plan of 1900 :

CEDRUS

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Cedrus Deodara : statistical results of deodar sample plot measurements in even-aged fully stocked crops.

Age. years.	Mean height.			Mean girth at $4\frac{1}{2}$ ft. from ground.			Number of stems per acre.			Volume of timber per acre in main crop. ¹		Mean annual incre- ment per acre, tim- ber in main crop. ¹		Age. years.
	I ft.	II ft.	III ft.	I ft.	II ft.	III ft.	I quality.	II quality.	III quality.	I cub. ft.	II cub. ft.	I cub. ft.	II cub. ft.	
20	28	15	6	1	2	0	950	1,380	1,700	1,000	..	33	..	20
30	47	26	12	1	10	0	610	1,050	1,400	2,800	..	70	..	30
40	64	38	18	2	6	1	400	750	1,100	4,500	..	90	22	40
50	79	50	26	3	3	2	280	500	800	6,300	1,100	105	40	50
60	88	62	34	4	0	2	200	360	550	8,000	2,400	114	53	60
70	106	73	42	4	8	3	160	280	420	9,600	3,700	120	62	70
80	118	83	50	5	4	3	130	220	340	11,300	5,000	125	70	80
90	126	92	57	6	0	4	110	190	290	12,900	6,300	129	77	90
100	134	101	64	6	7	4	100	170	250	14,300	7,700	130	82	100
110	140	107	70	7	2	5	90	150	230	15,900	9,000	131	84	110
120	144	112	75	7	8	5	85	130	200	17,100	10,100	129	85	120
130	147	115	78	8	2	6	80	120	180	18,000	11,100	125	83	130
140	150	117	80	8	8	6	75	110	160	18,800	12,400	..	..	140
150	153	118	81	9	1	6	70	100	140	..	..	..	..	150
160	155	119	82	9	6	7	..	90	120	..	..	..	..	160

¹ Solid volume of timber in the round (excluding bark) down to a girth (measured over bark) of 2 ft.; volume calculated from quarter-girth squared.

Cedrus Deodara : out-turn statistics, Hazara.

Diameter of tree at breast height.	Average out-turn.		Diameter of tree at breast height.	Average out-turn.	
	Logs.	Scantlings.		Logs.	Scantlings.
in.	cub. ft.	cub. ft.	in.	cub. ft.	cub. ft.
25	85	50	35	170	92
26	92	53	36	180	98
27	100	56	37	190	104
28	108	60	38	202	110
29	115	64	39	216	116
30	122	68	40	230	123
31	130	72	41	245	130
32	140	77	42	260	136
33	150	82	43	275	142
34	160	87	..	..	..

Chamba. In the Upper Ravi working plan of 1910, Mr. C. G. Trevor records the following scantling out-turn figures based on measurements of 176 trees :

Cedrus Deodara : scantling out-turn statistics, Upper Ravi forests.

Diameter of tree at breast height.	Out-turn of scantlings.	Diameter of tree at breast height.	Out-turn of scantlings.
in.	cub. ft.	in.	cub. ft.
24-25	38	32-33	83
26-27	45	34-35	94
28-29	55	36-37	100
30-31	75	..	..

The following actual scantling out-turns of 87 felled deodar trees are recorded by Mr. R. McIntosh in the Dalhousie range working plan :

Cedrus Deodara : scantling out-turn statistics, Dalhousie range forests.

Diameter of tree at breast height.	Number of trees measured.	Average out-turn of scantlings.	Diameter of tree at breast height.	Number of trees measured.	Average out-turn of scantlings.
in.		cub. ft.	in.		cub. ft.
18-19	4	25	28-29	14	71
20-21	6	33	30-31	12	68
22-23	7	37	32-33	7	74
24-25	24	45	34-35	4	88
26-27	8	52	36	1	80

Mr. J. Copeland recorded the following actual out-turns of felled trees in the revision felling statement for the Pangri forests, 1917 :

Cedrus Deodara : out-turn statistics, Pangri forests.

Diameter of tree at breast height.	Average out-turn.		Diameter of tree at breast height.	Average out-turn.	
	Logs.	Scantlings.		Logs.	Scantlings.
in.	cub. ft.	cub. ft.	in.	cub. ft.	cub. ft.
18-19	40	..	34-35	193	112
20-21	56	..	36-37	205	110
22-23	64	36	38-39	231	122
24-25	84	51	40-41	277	164
26-27	99	61	42-43	314	147
28-29	109	66	44-45	355	185
30-31	137	78	46-47	368	215
32-33	152	88	..	..	..

Kulu. The following yield table has been prepared by Mr. C. G. Trevor from measurements of 7,700 trees exploited in Kulu over a period of twenty years :

Cedrus Deodara : yield table, Kulu.

Diameter at 4½ ft.	Age.	Mean annual increment in sawn scantlings (general average).	Local quality I. (Trees attaining maximum height of over 120 ft.)		Local quality II. (Trees attaining maximum height of 90 to 120 ft.)		Local quality III. (Trees attaining maximum height of less than 90 ft.)		Average.	
			Logs.	Scant- lings.	Logs.	Scant- lings.	Logs.	Scant- lings.	Logs.	Scant- lings.
m.	years.	cub. ft.	cub. ft.	cub. ft.	cub. ft.	cub. ft.	cub. ft.	cub. ft.	cub. ft.	cub. ft.
12	57	0.16	26	13	20	10	15	7	20	9
13	61	0.18	31	15	24	12	18	8	24	11
14	65	0.20	37	18	28	14	21	9	28	13
15	68	0.22	43	21	32	16	24	11	32	15
16	71	0.25	50	24	38	18	28	13	37	18
17	75	0.28	58	28	44	21	33	15	43	21
18	80	0.30	66	33	51	24	38	17	49	24
19	85	0.32	76	38	59	27	44	19	56	27
20	90	0.33	86	43	68	31	50	22	63	30
21	95	0.36	100	48	74	35	56	25	70	34
22	100	0.39	114	54	82	40	63	28	77	39
23	105	0.42	126	61	93	45	70	31	86	44
24	110	0.44	140	68	103	50	78	35	95	49
25	115	0.47	158	75	114	55	83	39	105	54
26	120	0.49	170	82	123	60	90	43	115	59
27	127	0.50	183	89	133	65	97	47	126	64
28	135	0.52	191	96	142	71	104	51	137	70
29	147	0.52	200	102	150	77	111	55	147	76
30	159	0.51	207	109	160	83	119	60	157	82
31	171	0.51	215	115	168	89	127	65	167	88
32	205	0.46	223	120	178	94	134	70	177	95
33	..	..	229	126	185	99	142	75	187	102
34	..	..	234	131	193	104	150	80	197	109
35	..	..	238	136	202	109	159	85	209	117
36	..	..	243	141	208	114	168	90	221	125
37	..	..	248	145	214	118	177	93	233	133
38	..	..	253	149	220	122	186	96	244	140
39 and over	..	..	258	153	226	126	192	100	255	150

The standard loss in converting from logs to scantlings is taken locally to be 45 per cent.

Bashahr. Measurements of 439 trees felled in Bashahr between 1892 and 1910 gave the following results :

Cedrus Deodara : out-turn statistics, Bashahr.

Girth of tree at breast height.	Corresponding approximate diameter.	Average age.	Average out-turn.	
			Logs.	Scantlings.
ft.	in.	years.	cub. ft.	cub. ft.
6-7	23-27	97	84	38
7-8	27-31	112	123	59
8-9	31-34	128	168	..
9-10	34-38	162	223	..

Simla hills. The following statement shows the average out-turn obtained from 358 deodar trees felled in the Simla forest division during a series of years prior to 1914, and converted mainly into sleepers :

Cedrus Deodara : out-turn statistics, Simla hills.

Diameter.	Corresponding girth.	Logs.	Average out-turn.			
			Sawn timber.		Other sawn timber.	Total sawn timber.
			Broad-gauge sleepers. Number.	Volume. cub. ft.		
in.	ft. in.	cub. ft.		cub. ft.	cub. ft.	cub. ft.
24	6 3	96	11	45	7	52
26	6 9	104	12	49	9	58
28	7 4	114	13	53	12	65
30	7 10	125	14	57	15	72
32	8 5	137	16	66	13	79
34	8 11	151	18	74	13	87
36	9 5	166	20	82	13	95
38	9 11	182	22	90	13	103
40	10 6	200	25	102	10	112
42	11 0	220	27	111	11	122
44	11 6	240	29	119	13	132
46	12 1	265	31	127	15	142
48	12 7	290	33	135	18	153
50	13 1	320	35	143	22	165
52	13 7	350	37	152	25	177
54	14 2	380	38	156	34	190
56	14 8	415	39	160	43	203

The following table of measurements is contained in Mr. Hart's working plan of 1897 for the Simla municipal forests :

Cedrus Deodara : out-turn statistics, Simla municipal forests.

Diameter.	Age.	Gross volume.	Mean annual increment.
in.	years.	cub. ft.	cub. ft.
12-15	77	32.66	0.42
15-18	88	49.49	0.56
18-21	100	73.34	0.73
21-24	112	92.26	0.82

3. ABIES, JUSS.

The silver firs are evergreen trees with leaves flattened, except in a few species which have leaves quadrangular in section, always with a pair of white or greyish lines, one on either side of the midrib on the ventral surface. Flowers monoecious. Male flowers solitary in the axils of the leaves of the previous year's shoots; female flowers erect on the upper sides of the branches, usually near the top of the tree, composed of numerous spirally arranged imbricate ovuliferous scales with two ovules on each scale, and an equal number of longer mucronate bracts. Cones ripening in one season, erect, breaking up on the tree when ripe, the scales falling with the seeds and leaving the erect central axis of the cone, which persists for some time on the tree.

The specific distinction between the Himalayan silver firs is not yet a matter of certainty. *A. Pindrow*, Spach, is the low-level silver fir of the western Himalaya, and *A. Webbiana*, Lindl., is the name commonly given to the eastern form as well as to the high-level western form. Brandis,¹ who differentiates between (1) the western low-level form (*A. Pindrow*, Spach), (2) the western high-level form (*A. Webbiana*, Lindl.), and (3) the eastern form (*A. densa*, Griff.), doubts whether the three are specifically distinct.

¹ Indian Trees, p. 692.

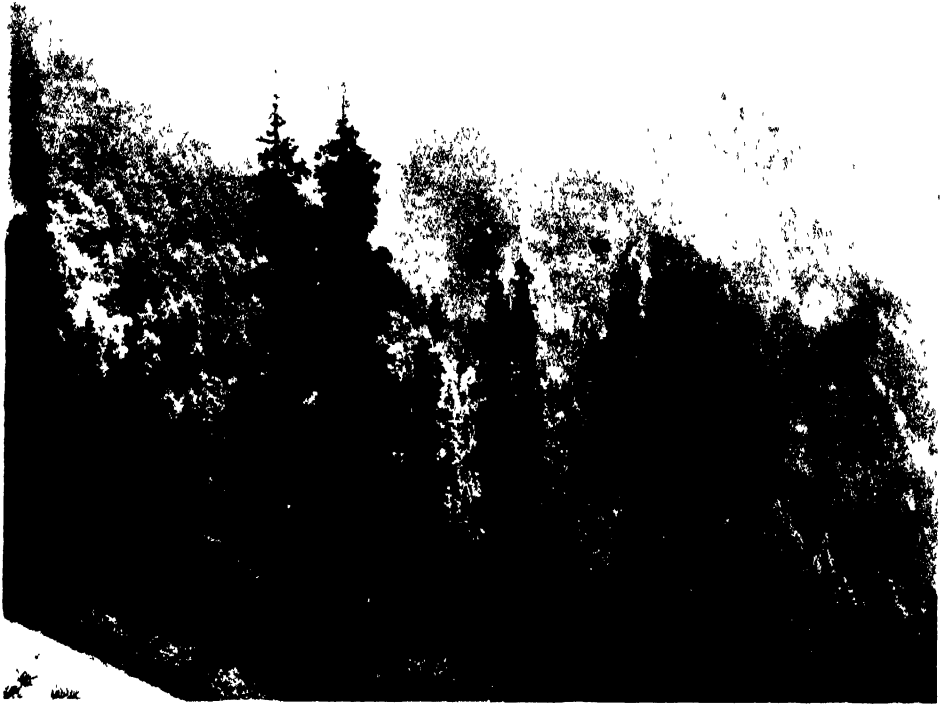


FIG. 465. *Abies Pindrow* with *Quercus semecarpifolia* at 10,000 ft., Kulu.



FIG. 466 Pure mature forest of *Abies Pindrow*, upper Siran valley, Hazara

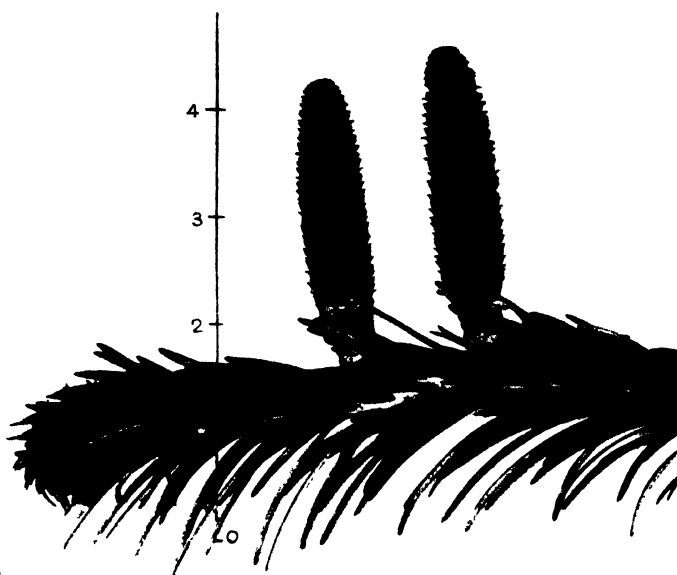


FIG. 467. *Abies Pindrow*, female flowers at time of pollination, May
Scale shows inches



FIG. 468. *Abies Pindrow*, cones at time of ripening, October

He says that in his experience the low-level form gradually changes into the high-level form on ascending to the higher ranges, and that he has never seen the two growing together. He mentions, however, that the two western forms have hitherto come true to seed when cultivated in England and Ireland. Henry¹ distinguishes two species, *A. Pindrow*, Spach, the western low-level fir, and *A. Webbiانا*, Lindl., the eastern fir, and considers the high-level western form to be a variety (var. *brevifolia*) of the latter.

The low-level western silver fir is markedly different from the eastern form in general appearance, as will be seen on comparing Figs. 465 and 473. The main differences in the three forms are as follows :

1. Western low-level form (*A. Pindrow*): a tall tree with a dense narrow conical crown and distichous leaves, 1-2.5 in. long or even longer ; young shoots glabrous ; cone erect, cylindrical-ovoid, 4-7 in. long by 2-2.5 in. in diameter ; bracts in the mature cone less than half the length of the scales, with emarginate apex.

2. Western high-level form : very similar to *A. Pindrow*, but usually more stunted and gnarled ; leaves 0.5-1 in. long, densely covering the upper sides of the twigs ; young shoots with short brown hairs ; cones shorter and thicker than in *A. Pindrow*.

3. Eastern form : a tall tree with thick spreading horizontal branches and leaves 1-2 in. long, more or less distichous, but more crowded than in *A. Pindrow* ; young shoots hairy ; cones shorter and thicker than in *A. Pindrow* ; bracts in the mature cone nearly as long as the scales, with a stiff acuminate apex.

Species 1. *A. Pindrow*, Spach ; 2. *A. Webbiانا*, Lindl. ; 3. *A. Webbiانا*, Lindl. (?), (*A. densa*, Griff.).

1. *Abies Pindrow*, Spach. West Himalayan low-level silver fir. Vern. *Paludar*, *rewar*, Haz. ; *Tós*, Kulu ; *Rai*, Chamba ; *Pindrau*, *rau*, *kalrai*, Simla hills ; *Span*, *krok*, Bashahr ; *Morinda*, Jaunsar ; *Ragha*, Kumaun.

A tall evergreen tree with a dense conical crown of dark green foliage, which frequently extends the whole length of the bole almost to the ground ; upper branches horizontal, lower ones usually drooping with ends curving upwards, branchlets stiff, spreading horizontally. Leaves 1-2.5 in. long, sometimes longer, 0.1 in. broad or less, flat, narrow linear, dark green and shining above, with two whitish lines below, one on either side of the midrib, apex usually bifid. Leaves spirally arranged, declinate into a pectinate arrangement on barren shoots, but on cone-bearing shoots shorter, not pectinate but arranged more or less round the shoot, especially on the upper side, and pointing somewhat forward. Bark on young trees brown to silvery and smooth or scaly, on old trees greyish brown to light grey with deep vertical fissures and long, narrow scales. Wood white, used for building, planking, boxes, shingles, &c. and suitable for match-manufacture and wood-pulp. The lower part of the bole often contains brown wood in the centre, as in the case of the spruce (see p. 1143). Although commonest in large trees it is sometimes found in trees of moderate size.

The tree reaches large dimensions. The following have been recorded in Jaunsar :

¹ Elwes and Henry, *The Trees of Great Britain and Ireland*, iv. 750, 755.

Near Mundali : (1) height 206 ft., girth 18 ft. 9 in. ; (2) height 202 ft., girth 26 ft. ; (3) height 188 ft., girth 19 ft. 9 in. ; (4) girth 26 ft.

Near Kathiyan : (1) height 195 ft., girth 13 ft. ; (2) height 189 ft., girth 16 ft. ; (3) height 181 ft., girth 15 ft. 8 in.

DISTRIBUTION AND HABITAT. This fir extends throughout the western Himalaya from Afghanistan to Nepal, chiefly at 7,500 to 11,000 ft., but sometimes descending below 7,000 ft. in cool ravines or ascending to 12,000 ft. It is commonly found mixed with spruce (*Picea Morinda*) and sometimes with deodar or blue pine ; in the latter case the silver fir usually seeks the cooler and moister slopes and the pine the warmer and drier situations. There are certain localities where the usual spruce mixture is absent and the silver fir forms pure forests or is mixed with broad-leaved species. Such is the case almost throughout the Galis forests of Hazara, on the Dhaulā Dhar in Kangra, in parts of Kumaun, as on Badkot mountain, and in many other localities on cool aspects at the higher elevations. The silver fir is also frequently found associated with various broad-leaved species, such as *Quercus dilatata*, *Q. semecarpifolia* (at the higher elevations), *Acer caesium* and other maples, *Aesculus indica*, *Prunus Padus*, *Ulmus Wallichiana*, *Juglans regia*, and other trees. This broad-leaved mixture is well represented in Hazara, where also a very common associate of the silver fir is the yew (*Taxus baccata*). In areas not subject to grazing there is often a dense undergrowth of shrubby and herbaceous plants, among the commoner shrubs being species of *Rubus*, *Rosa*, *Viburnum*, *Salix*, and *Strobilanthes*, and the gregarious aromatic shrub *Skimmia laureola* ; bamboos, particularly *Arundinaria spathiflora*, are plentiful in some localities. The trees are often festooned with the so-called Himalayan Virginia creeper (*Vitis semicordata*). The fir forests, however, are very often used as summer grazing grounds, in which case undergrowth is kept down.

Figs. 472 and 475 show the common type of spruce and silver fir mixture. Figs. 464 and 465 illustrate the pure type of silver fir forest commonly found at the higher elevations, with *Quercus semecarpifolia* growing wherever there is sufficient light ; in Fig. 464 is seen a portion of one of the high-level pasture grounds which frequently adjoin the fir forests. Fig. 466 shows the interior of a pure silver fir forest in Hazara. Well-stocked silver fir forests are of considerable density, admitting little light to the ground owing to the thick dark green foliage. The stately appearance of the lofty trees, coupled with their heavy shade, gives an air of grandeur to these forests which is not equalled in any other type of forest in the Himalaya.

The silver fir prefers cool, moist situations with deep, rich soil, and is found most commonly on northerly aspects, though at the higher elevations it is found on all aspects. It avoids dry, shallow soil, and though sometimes found on the tops of ridges it is usually stunted in such situations. The silver fir forests occur within the region of heavy snowfall, and the depressions running down the mountain sides are filled for several months with deep snow or scoured by snow-slides ; the fir avoids these depressions, occupying the intervening spurs, while the depressions are either devoid of tree-growth or clothed with broad-leaved trees. Within the natural habitat of the silver fir the rainfall, including the winter snowfall, varies for the most part from 45 to 100 in. ; most of the rain falls during the monsoon, from July to September,

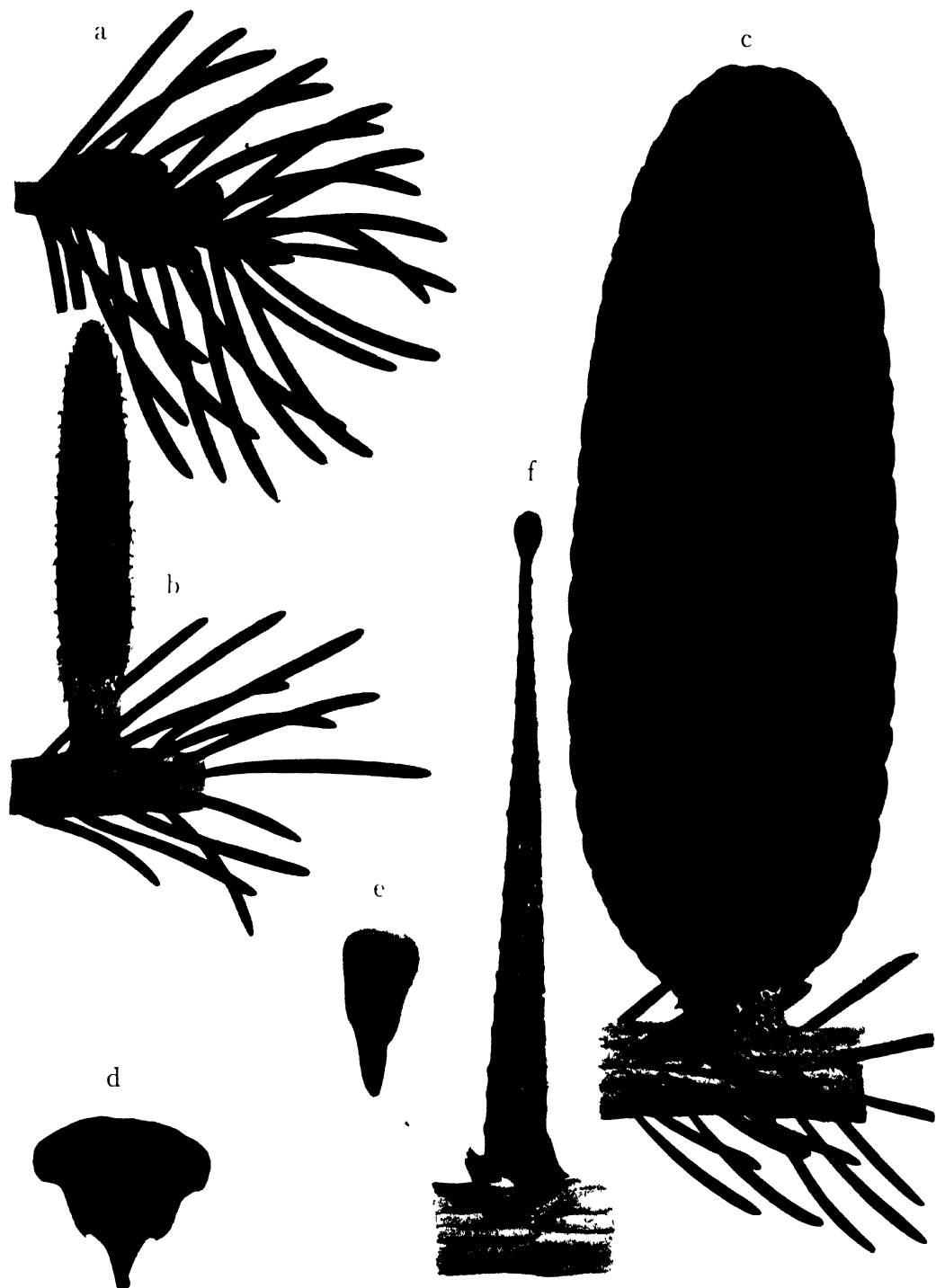


FIG. 469. *Abies Pindrow*—FLOWERS AND FRUIT $\times \frac{7}{8}$

a Male flowers, April-May b—Female flower at time of pollination, April-May
 Mature cone, October-November d—Cone scale e—Seed f— Persistent cone axis

and the snow falls from December to April. The maximum shade temperature probably seldom, if ever, reaches 90° F. The fir does not extend into the dry regions of the upper Sulej valley.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The needles persist for three to six years, and sometimes in part for seven or eight years. The old needles fall chiefly in May and June. The new shoots appear in April–May, their bright green colour contrasting strongly with the dark green of the older foliage; the young needles and shoots are soft, not stiff like the older ones.

Male flowers (Fig. 469, *a*) sessile in the axils of the leaves on the lower side of the previous year's shoots, cylindrical-ovoid, 0.3–0.5 in. long by 0.2 in. in diameter immediately before ripening, enlarging to 0.5 to 0.8 in. by 0.2 to 0.3 in. after shedding pollen, yellow, often with a light purplish colour, subtended at the base by a cup of brown imbricate scales which persist after the flowers have fallen. The pollen is shed chiefly towards the end of April and in the first half of May, and the flowers fall soon after.

Female flowers (Figs. 467 and 469, *b*) on stout scale-covered stalks 0.4–0.5 in. long, erect on the horizontal branches, chiefly on the upper part of the tree, 1.5–2 in. long by 0.4–0.5 in. in diameter, cylindrical, dark purple, with ovuliferous scales and longer bracts with minutely fimbriate margins arranged in spirals of 5 × 3. Pollination takes place chiefly towards the end of April or in the first half of May, at which time the scales are open to receive the pollen. They close soon after, and the growth of the young cone is rapid. At low elevations by the end of June the cones are about 4–5 in. long by 1.75 in. in diameter.

Cones (Figs. 468 and 469, *c*) when mature erect cylindrical-ovoid, 4–7 in. long by 2–2.5 in. in diameter, dark purple. Scales (Fig. 469, *d*) 1–1.2 in. long by 1.2–1.5 in. broad, fan-shaped, bearing two winged seeds (Fig. 469, *e*) about 1–1.3 in. long, including the wing and 0.5–0.6 in. long without it; wing 0.5–0.8 in. wide. Bracts broadly obovate emarginate, less than half the length of the scales. The cones ripen in October or early November, breaking up on the tree, and the seeds and scales fall together, leaving the central axis (Fig. 469, *f*), which persists for some years on the tree.

Seeding. The period which elapses from the pollination of the female flower to the ripening of the cone is thus six to seven months, and a probable good seed-year can be foretold by that length of time by examining the upper branches of the trees in April or May with the aid of field-glasses, care being taken not to confound the flowers with the old cone-axes; the former are usually found in quantity nearer the top of the tree than the latter.

In order to obtain seed for sowing purposes the cones have to be collected before they break up, towards the end of September or early in October; the cones break up on being placed in the sun for a few days, and the seeds may be separated from the scales by shaking and winnowing. Tests have been carried out to ascertain the effect of the age and size of the tree on the fertility of the seed, but so far as they go they have not shown any definite relation between age or size and fertility. In Kulu seed from trees 12 to 18 ft. in girth gave an average fertility of 69 per cent. Nevertheless large trees often tend to become dry-topped, and such trees produce few or no cones even in good seed-years. Special observations in this direction were made during an

exceptionally prolific seeding in Hazara in 1918. It was noticed that cones were produced in greatest abundance by moderate-sized trees about 3 to 7 ft. in girth, while large dry-topped trees were as a rule poor seed-bearers. It was further ascertained that cones began to be produced in fair quantity at thirty years of age, though on exposed ridges and other unfavourable situations the age was higher; younger trees, however, were occasionally found to produce a few cones.

Seed-year records in Jaunsar for twenty-five out of twenty-eight consecutive years, 1887 to 1914, showed good seeding seven times, moderate seeding five times, and bad seeding thirteen times, from which it would appear that a good seed-year may be expected about once in every three to four years.

GERMINATION (Fig. 470, *b-h*). Epigeous. The radicle emerges from the apex of the seed, opposite the wing, and descends. The hypocotyl, at first curving downwards, straightens in elongating, and raises above ground the cotyledons enclosed in the shell of the seed. The latter, with the endosperm, remains enclosing the tips of the cotyledons as they elongate, eventually falling to the ground, when the cotyledons, 5-7 in number, spread out radially in a whorl, from the centre of which the young shoot subsequently develops.

THE SEEDLING. The following is a description of the natural forest seedling during the first three years:

First year (Fig. 470, *i*). *Roots*: primary root short or moderately long, terete, tapering, wiry, brown; lateral roots absent or short. *Hypocotyl* distinct from root, 1-2.2 in. long, terete, glabrous, red or reddish green turning brown; point of junction between hypocotyl and root marked in early stages by the loose ruptured epidermis. *Cotyledons* 5-7, whorled, 0.8-1.3 in. long, 0.06-0.08 in. broad, linear, flattened, often curved laterally, entire, apex emarginate, at first pale green, turning dark green with whitish stomatic lines on either side of the midrib on the upper surface. *Stem* (above cotyledons) consisting of nothing more than a whorl of leaves equal in number to the cotyledons and alternating with them, and a winter bud of brown imbricate scales in the centre. *Leaves* 0.3-0.6 in. long, linear, narrowed at the base, flattened, entire, apex rounded or acute or emarginate, upper surface smooth and shining, lower surface with a pair of silvery stripes, one on either side of the midrib, composed of parallel lines of stomata.

Second year (Fig. 470, *j*). *Roots*: primary root moderately long, wiry, brown; lateral roots moderate in number, short or moderate in length. *Hypocotyl* dark brown, wiry, smooth or peeling longitudinally. *Cotyledons* still present and green throughout the season, or sometimes turning yellow or brown. *Stem*: first year's shoot (above cotyledons) represented by a whorl of leaves much shorter than the cotyledons and the winter bud scales immediately above them; second year's shoot erect, pale yellowish grey, with numerous spirally arranged leaves 0.4-1.2 in. long, the silvery stripes on the under surface more conspicuous than those on the first year's leaves. *Buds*: terminal bud prominent, globose or ovoid, greenish reddish or purplish brown, often white with resin; sometimes two terminal buds together, both of which produce shoots next year, of which one eventually takes the lead; one or more axillary buds sometimes produced.

Third year. *Roots*: primary root elongated somewhat; lateral roots often numerous, short to moderately long, fibrous. *Hypocotyl* brown, peeling in longitudinal strips. *Cotyledons* usually dropped, their position clearly marked by a raised ring; sometimes a few left, yellow or brown. *Stem*: first year's shoot (above cotyledons) with whorl of needles usually present, in part at least, often turning yellow, and winter bud scales distinct immediately

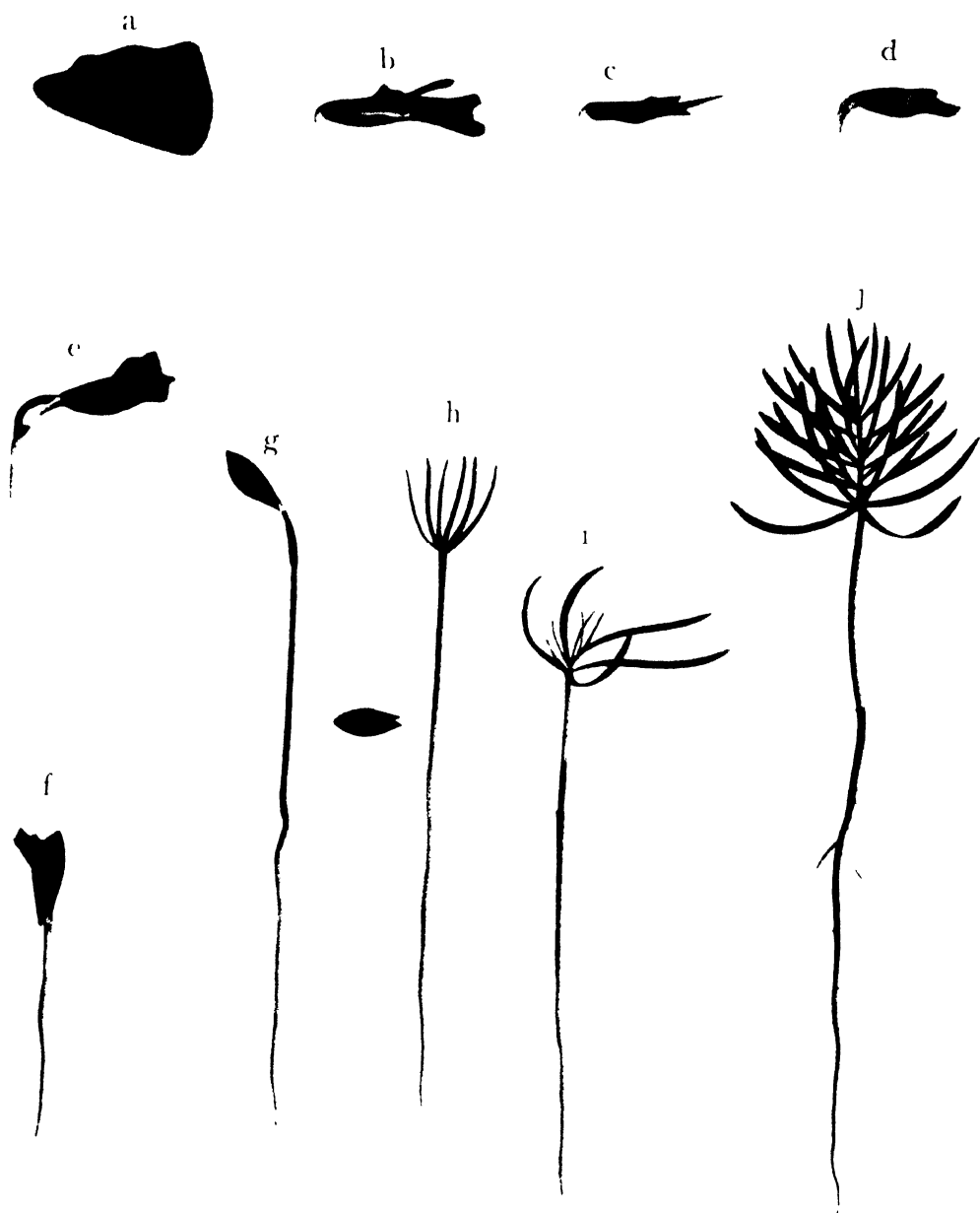


FIG. 470. *Abies Pindrow*—SEEDLING $\times \frac{3}{4}$

a—Seed b - h---Germination stages (e shows ruptured epidermis at base of hypocotyl)
 i Seedling at end of first season j--Seedling at end of second season

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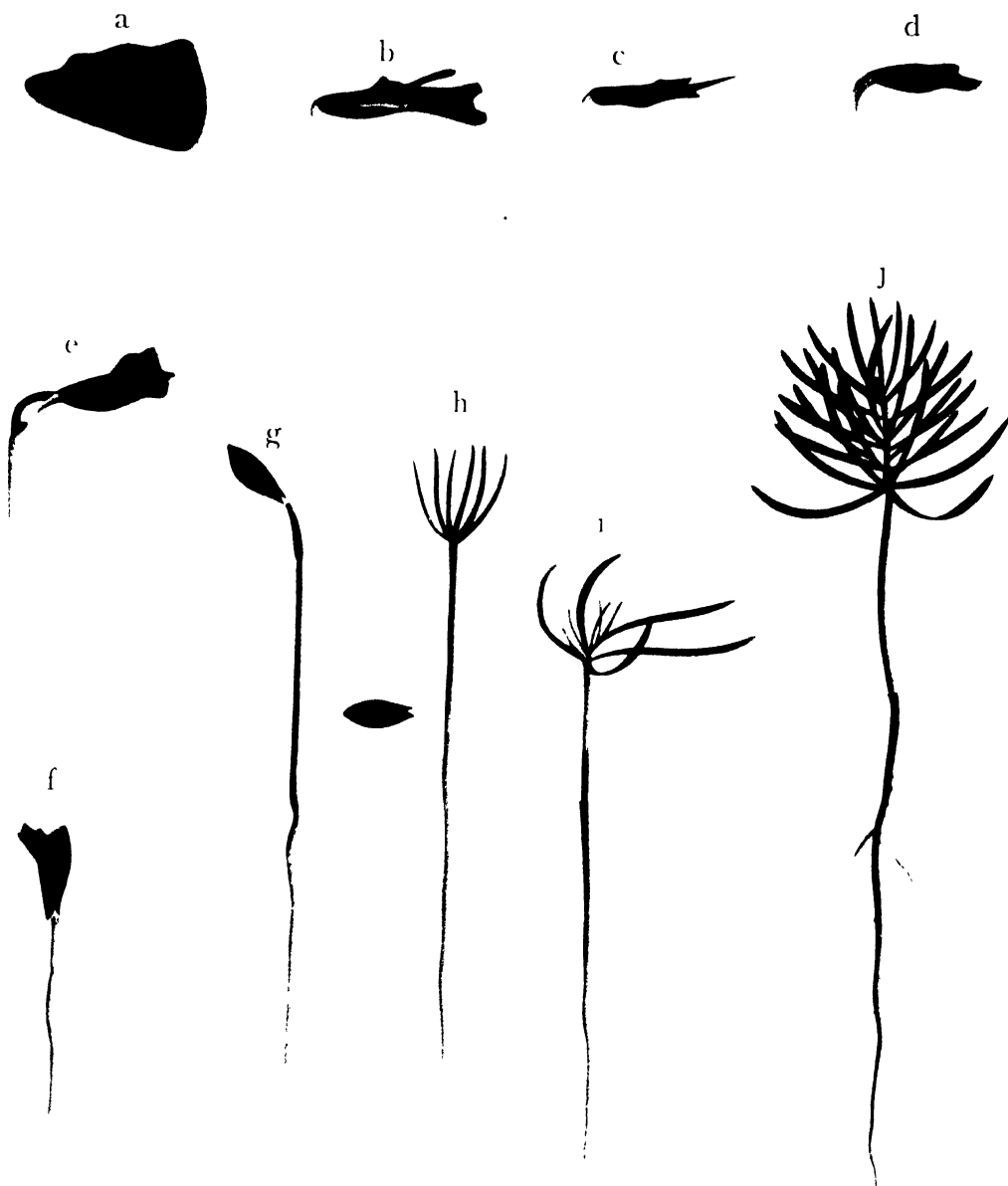


FIG. 470. *Abies Pindrow*—SEEDLING $\times \frac{3}{4}$

- a Seed b - h Germination stages (e shows ruptured epidermis at base of hypocotyl)
 i Seedling at end of first season j—Seedling at end of second season

above them; second year's shoot greyish brown, with leaves usually all present, sometimes a few fallen on lower part of shoot; third year's shoot pale yellowish grey, covered with spirally arranged leaves 0.7–1.5 in. long, silvery stripes on lower surface more conspicuous than on leaves of previous year's shoot. *Buds*: terminal buds one or two, as before; lateral axillary buds usually also present.

The leaves of seedlings persist for at least three and often four years, and sometimes in part for five years. They increase slightly in size with each succeeding year, attaining a length of about 1–1.7 in. in the sixth year. Each year's growth is clearly marked by the rings of terminal winter bud-scales, which persist for some years. The season's growth commences in April or early May, and is practically completed by the end of June. The growth of natural seedlings is slow. The first year's growth is very little more than the length of the hypocotyl, that is, a maximum of a little over 2 in. The second year's growth ordinarily varies from 0.4 to 1.3 in., and that of the third year from 0.5 to 2.8 in., according to vigour; subsequent growth is usually somewhat faster, but even under favourable conditions a height of barely 3 ft. is attained in ten years. Thus in counting rings on stumps a period of at least ten years should be added for the time required for the seedling to attain stump height.

Seedlings require a moist fresh soil for their best development. They are sensitive to drought and frost. They stand a considerable amount of shade, but when once established are apt to become suppressed under heavy shade, and grow most vigorously with complete overhead light. They are readily browsed in the spring, particularly by goats.

SILVICULTURAL CHARACTERS. The silver fir is a shade-bearer. Saplings persist for many years under fairly heavy shade, and suffer less thereby than those of any other conifer of the western Himalaya except the yew, but they put on little growth unless a fair amount of overhead light is admitted; the admission of complete overhead light after the young plant is established results in vigorous upward growth if other conditions are favourable. For the production of clean timber, however, side shade is essential, owing to the great tendency of the tree to form branches low down on the bole. In a mixed forest of spruce and silver fir the latter may be found with leafy branches down the bole under conditions of shade in which the spruce boles are kept clean.

The root-system of the silver fir is somewhat superficial, spreading, and not very massive. Trees on exposed situations are apt to be thrown by wind, but as a rule the fir grows in sheltered situations. In its natural home the tree does not appear to suffer to any extent from frost, though young plants are sometimes affected; in Britain it is a tender species. It suffers little from snow-break, owing to its short branches, though on steep slopes curvature at the base is frequently caused in the sapling stage by sliding snow. Fires do not often occur in the silver fir forests of the western Himalaya, but when it is subjected to fire the fir is more sensitive to injury than any other conifer of that region, trees which are badly scorched being usually killed outright.

NATURAL REPRODUCTION. Under natural conditions the seed which falls in October and November germinates for the most part during the following May and early June. The seed may be found germinating under fairly heavy shade. The question of seed-bearers may be of importance in over-mature

forests in which the trees are old and dry topped ; the quantity of seed produced by such trees, as already mentioned, is small.

The chief requirements for successful reproduction, apart from the question of seed-production, are a germinating bed consisting of fresh well-drained porous soil, preferably newly exposed mineral soil, an absence of sour humus or excessive soil-moisture, protection in the earlier stages from the desiccating effect of the sun, protection from grazing and from fire—though the latter is seldom to be feared—and a fair amount of overhead light after the seedling is established. The value of newly exposed mineral soil may be seen by the manner in which seedlings spring up in cuttings, and on places where the soil has been exposed by the felling and extraction of timber or otherwise ; in some of the Kashmir forests thickets of silver fir spring up on newly formed islands of sand, shingle, and boulders in the beds of streams running through the forest. Drought is a fruitful cause of mortality among natural seedlings, which die off in quantity during or shortly after germination on ground which is exposed to the sun for any length of time during the day ; shade, at all events from the side, is essential under most conditions.

Perhaps the most general cause of failure in natural reproduction is attributable to unfavourable soil conditions, possibly the result of an excess of carbon dioxide produced by an accumulation of dead needles in the presence of an excess of moisture in the soil. These unfavourable conditions are sometimes indicated by the presence of an undergrowth of *Skimmia Laureola*. To this cause is probably due the almost complete failure of reproduction in some of the moister fir forests, for example in the Dungagali range of Hazara. Here reproduction is almost entirely absent in the moister depressions, though it appears on the better drained spurs, while in places where the soil has been worked up, reproduction sometimes appears in quantity where it was previously absent. This, together with the experience gained in the Kanjatra block, near Deoban, in Jaunsar, indicates that the unfavourable soil conditions do not go deep, and that they can be dissipated by the simple process of exposing the soil and hoeing it up. The Kanjatra block consisted at one time of dense mature spruce and silver fir forest which showed no signs of regenerating, and accordingly in 1877–8 it was opened out in the form of a heavy seeding felling, but the only result was a dense crop of weeds without any natural reproduction. Artificial reproduction was then tried, and the silver fir seedlings established themselves without difficulty in the prepared lines where the soil was dug up. The result has been a complete success, there being now a promising young crop of silver fir under the mature and somewhat open overwood, which is ready for removal. In this case the unfavourable soil conditions were evidently removed without difficulty by the mere hoeing up of the soil, otherwise the seedlings, of which some were the result of direct sowing and some were transplants, could not have survived. In cases where reproduction fails owing to unfavourable soil conditions, these unfavourable conditions could no doubt be removed by measures similar to those which have been found so successful in the case of the deodar, namely, cutting the undergrowth and burning all refuse ; in the case of the silver fir, however, more caution would be required in opening the canopy than in the case of the deodar, owing to the sensitiveness of the seedlings to drought.

Except in special cases such as those just noted, in which the reproduction of the silver fir fails owing to unfavourable soil conditions, natural reproduction is usually all that can be desired provided the ground is not exposed for any length of time to the desiccating effect of the sun. Thickets of young silver fir are often to be found in small gaps in which side shade to the ground is afforded, or under a moderately light canopy of broad-leaved species, blue pine or deodar, or on cool northerly slopes. There are many instances in which broad-leaved or other crops are being gradually converted to silver fir crops owing to the readiness with which the fir establishes itself on suitable ground under a light canopy of other species or in small gaps. Fig. 471 shows the typical manner in which thickets of young silver fir often appear in gaps in broad-leaved forest.

Moderate shrubby weed-growth does not as a rule impede the natural reproduction of the fir, and may be beneficial in sheltering the ground from the sun. Where the weed-growth is very dense, however, it is inimical; this applies particularly to rank herbaceous growth, which is specially noxious. A dense matted growth of *Strobilanthes* impedes natural reproduction in some localities. *Skimmia Laureola*, as already noted, usually denotes unfavourable soil conditions.

Natural reproduction has little or no chance of establishing itself in areas which are at all heavily grazed, as the young plants are very susceptible to damage, while apart from actual browsing the seedlings, owing to their small size, are very liable to be uprooted and destroyed by trampling.

ARTIFICIAL REPRODUCTION. Experience regarding the artificial reproduction of the silver fir is somewhat limited, as this tree has not been raised in plantations to any great extent. So far as is known transplanting from the nursery has generally proved more successful than direct sowing. Fresh seed should be sown in October or November, and it is usual to keep the plants three or four years in the nursery, which should be in a cool well-drained situation on fresh fertile loamy soil. The restocking of the Kanjatra block referred to above was commenced in 1885 and continued for some years; it took the form of contour line sowings and basket planting under an opened-out overwood of spruce with a little silver fir. Actually spruce and silver fir were sown in alternate lines 6 ft. apart, but very few of the spruce plants survived, though the silver fir plants have succeeded well over a considerable portion of the area. The cost, which is not accurately known, is said to have been high, but this was due partly to the experimental nature of the work and partly to the failure of the spruce, necessitating much restocking of gaps. Fig. 472 shows a portion of this plantation at the age of twenty-one years.

SILVICULTURAL TREATMENT. The silver fir forests of the western Himalaya have hitherto been worked under the selection system, but this system has not proved successful except under conditions specially favourable to natural reproduction. Such conditions do not as a rule exist in the purer types of silver fir forest where there is an excessive accumulation of fir needles on the ground. In mixed forests of silver fir with blue pine or broad-leaved species the fir usually reproduces with freedom, and the only course necessary as a rule is to open the canopy sufficiently to enable the young fir to establish itself. In the purer types of silver fir forest or in mixed forests of spruce and silver fir,

where conditions for natural reproduction are so often unfavourable, the plan indicated for securing reproduction is to open the canopy moderately and in good seed-years to cut the undergrowth and burn it thoroughly together with all felling refuse in the manner described for the deodar (p. 1122). It may prove difficult, however, to burn such material in the moister types of forest, in which case possibly hoeing the ground may have the desired effect. The question of side shade, as afforded by fellings in narrow strips, is worth pursuing experimentally in connexion with the natural reproduction of the silver fir. Fig. 482, which is explained on p. 1150, shows a successful case of reproduction of silver fir, spruce, and oak springing up on a cleared strip sheltered laterally from the morning sun. In places where reproduction cannot be secured by natural means artificial reproduction has to be resorted to in order to ensure complete stocking. In a species like the silver fir, which has such a tendency to branch low down, the cleanest timber will be produced by growing the trees in dense even-aged crops. The silver fir is well adapted for growing in such crops, and under natural conditions they are not infrequently met with.

In the more recent working plans the tendency now is to abandon the selection system in favour of successive regeneration fellings, under which special measures such as cutting and burning the undergrowth are to be carried out where natural reproduction cannot be obtained otherwise. For the silver fir a fairly long regeneration period is indicated owing to the sensitiveness of the young plants to exposure to the sun at too early a stage. In the latest working plan for Kulu a rotation of 150 years, with five periodic blocks of thirty years each, has been adopted. In Hazara a regeneration period of thirty years has also been proposed.

STATISTICAL. 1. *Girth and height increment.* For several years the rate of growth of the silver fir is slow, but after normal height-growth begins it is maintained fairly constantly at about 1-1½ ft. per annum up to an age of about 100-120 years, after which it usually slows down. The height-growth of the young plants in the Kanjatra plantation in Jaunsar was approximately as follows :

Abies Pindrow : rate of growth in Kanjatra plantation.

Age. years.	Mean height. ft.	Age. years.	Mean height. ft.
8	1.5	16	5.3
10	2.1	18	6.5
12	3.1	20	7.8
14	4.1		

Specially vigorous plants showed considerably faster growth. The statement below, showing the rate of growth of natural silver fir in girth and height, has been prepared from measurements recorded in working plans and based on ring-countings on stumps. The girth figures include bark, and in order to make the figures uniform for comparison nothing has been added to allow for the time required for a seedling to attain stump height ; in using the figures in practice, at least ten years should be added to the age to allow for this.



FIG. 471. Natural reproduction of *Abies Pindrow* establishing itself in a gap in forest of broad-leaved species, Hazara . *Acer caesium* in centre.

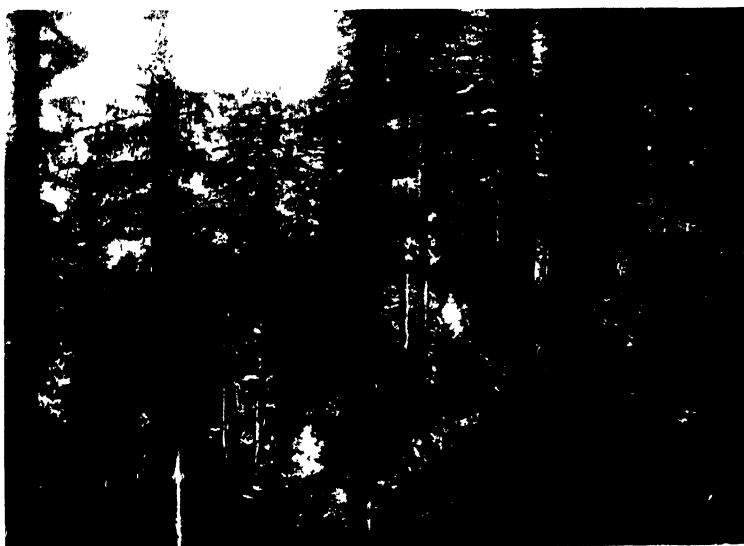


FIG. 472. Forest of *Picea Morinda* and *Abies Pindrow* opened out and underplanted with *Abies Pindrow*; young crop 21 years old; Jaunsar

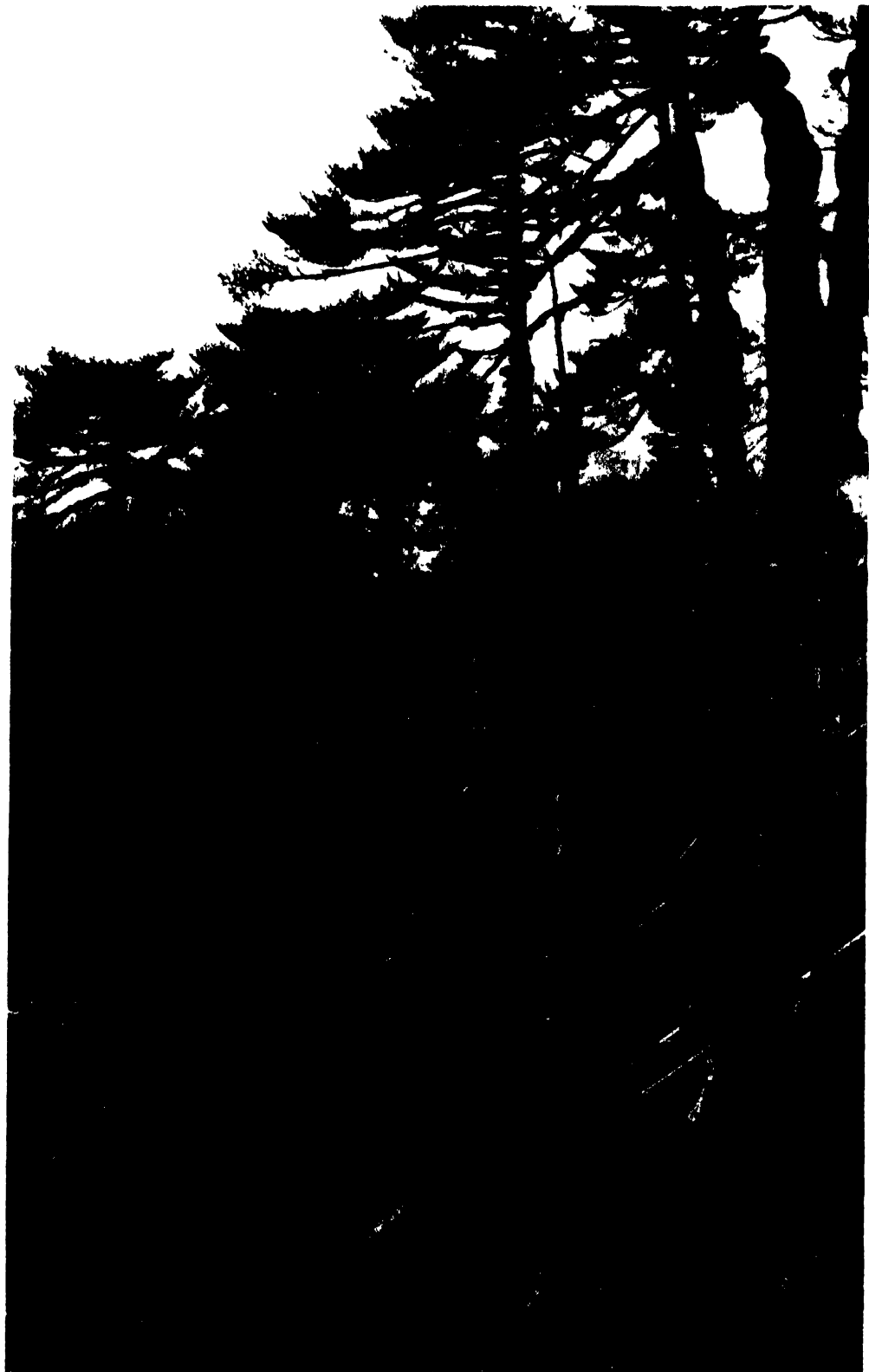


FIG. 473. Forest of *Abies Webbiana*, 11,000 ft. British Sikkim.

Abies Pindrow : rate of growth in girth and height in natural forests.

Age. years.	Mean girth.				Hazara. Dungagali and Thandiani ² (72 trees).	Kashmir.		Mean height.
	Kulu. ¹ Inner Saraj (20 trees).	Outer Saraj (19 trees).	Kulu (25 trees).	Rupi (29 trees).		Batot range. ³	Jaunsar. ⁴	
	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft.
20	..	..	..	..	..	0 10	1 4	20
40	2 6	..	..	2 11	1 8	1 10	2 9	40
60	3 7	2 10	..	4 4	2 10	2 9	4 2	60
80	4 6	3 9	3 3	5 6	3 11	3 9	5 6	80
100	5 4	4 8	3 11	6 8	4 11	4 9	6 10	100
120	6 1	5 6	4 7	7 8	5 11	5 9	8 2	120
140	6 10	6 5	5 3	..	6 11	6 10	..	..
160	7 8	7 3	5 9	..	7 10	7 11	..	..
180	..	8 1	6 3	..	8 6	9 2	..	..
200	..	..	6 9	..	9 0	..	..	..
220	..	..	7 3	..	9 4	..	..	..
240	..	..	7 9	..	..	..	..	..

In the working plan for the Dalhousie range forests, Chamba,⁵ it is estimated that an average tree takes 150 years to reach a diameter of 24 in. (girth, 6 ft. 3 in.), and shows no marked diminution of growth until after reaching a diameter of 36 in. (girth, 9 ft. 5 in.).

2. *Out-turn.* There are very few out-turn figures available for the silver fir. The following local yield table for Kulu has been compiled by Mr. C. G. Trevor for silver fir and spruce combined :

Abies Pindrow and *Picea Morinda* : yield table, Kulu.

Diameter at 4½ ft. in.	Age of spruce. years.	Age of silver fir. years.	Average age of the two species. years.	Mean annual increment of sawn scantlings. cub. ft.	Average volume.		Volume of trees for calculation of the yield.
					Logs. cub. ft.	Scant- lings. cub. ft.	
12	57	73	65	0.15	20	10	35
13	61	80	70	0.20	26	14	
14	65	86	75	0.24	32	18	
15	69	90	79	0.26	38	21	
16	73	96	84	0.29	44	25	
17	77	100	88	0.32	52	29	
18	81	104	92	0.36	60	34	90
19	85	112	98	0.40	70	40	
20	89	118	103	0.44	82	46	
21	93	122	107	0.49	96	53	
22	97	128	112	0.54	110	61	
23	101	134	117	0.59	126	70	162
24	105	139	122	0.65	144	80	
25	111	146	128	0.70	162	90	
26	115	150	132	0.75	180	100	
27	120	158	139	0.79	200	110	
28	125	164	144	0.81	220	118	219
29	129	172	150	0.84	236	126	
30	133	178	155	0.86	250	134	
31	137	186	161	0.87	264	141	
32	143	194	168	0.87	276	147	
33	150	..	..	..	288	153	290
34	155	..	..	..	300	159	
35	160	..	..	..	310	165	
36	165	..	..	..	320	170	
37	170	..	..	..	328	175	
38	175	..	..	..	336	180	
39 and over	183	..	..	..	344	185	350

¹ Working Plan for the Kulu Forests, Punjab, C. P. Fisher, 1898.

² Working Plan for the Dungagali and Thandiani Ranges, Hazara, A. V. Monro, 1908.

³ Working Plan for the Batot Range Forests, Riasi Division, Kashmir, Hans Raj, 1917 (these measurements include both spruce and silver fir).

⁴ Working Plan for the Jaunsar-Bawar Forests, P. H. Clutterbuck, 1901.

⁵ Revised Working Plan for the Dalhousie Range Forests, Chamba, R. McIntosh, 1913.

In the 1913 working plan for the Dalhousie range forests, Chamba, the average out-turn in sawn scantlings from 14 trees 24 to 30 in. in diameter at 4½ ft. from ground-level is stated to be 57 cubic ft. ; it was found, however, that the out-turn varied greatly in individual trees, owing to the presence of decay in some of them.

2. *Abies Webbiana*, Lindl. West Himalayan high-level silver fir. Vern. as for *A. Pindrow*.

A tree resembling *A. Pindrow* but usually more stunted and gnarled, with leaves 0·5–1 in. long (see introduction to this genus).

This fir is found in the western Himalaya at higher elevations than *A. Pindrow*, occurring towards the upper limits of tree-growth, sometimes associated with *Betula utilis* and *Rhododendron campanulatum*, ascending to 14,000 ft., and rarely descending below 11,000 ft.

3. *Abies Webbiana*, Lindl. (?). Syn. *A. densa*, Griff. East Himalayan silver fir. Vern. *Gobre salla*, Nep. ; *Dunshing*, Bhutia.

A tall evergreen tree, attaining a height of 200 ft., with thick spreading horizontal branches and leaves 1–2 in. long (see introduction to this genus).

This fir is found in the eastern Himalaya, in Sikkim and Bhutan, at 9,000–13,000 ft., sometimes descending in Bhutan to 8,000 ft. It probably extends into Nepal. Above 10,500 ft. it often forms pure forests of considerable extent (see Fig. 473) ; below this elevation it is sometimes mixed with spruce or hemlock spruce. At the higher elevations it becomes stunted, and is often associated with juniper. Characteristic undergrowth species are various rhododendrons or the *malig* bamboo (*Arundinaria racemosa*).

If protected from fire the silver fir forms crops of considerable density, but where fires rage the crop tends to become open, as the fir is sensitive to damage by fire, which often burns with great intensity owing to the dense growth of *malig* bamboo, and trees of fair size are killed outright by it.

The silver fir forests are situated for the most part in a very humid region characterized by heavy rain and dense mists from June to October, and the trees bear evidence of this in the growth of mosses, ferns, and other epiphytes with which their branches are often laden.

Measurements by Mr. E. Marsden in 1917 in three sample plots in the Darjeeling hills gave the following results :

Abies Webbiana : sample plot measurements, Darjeeling hills.

Standing crop (after thinning).							Yield from thinning in 1917.		Particulars of sample plot.
Age. years.	Number of stems per acre.	Mean girth. in.	Mean height. ft.	Solid volume per acre.			Number of stems per acre.	Solid volume per acre, timber and small- wood. cub. ft.	
				Timber over 24 in. in girth. cub. ft.	Small- wood. cub. ft.	Total. cub. ft.			
20	638	12.3	17	..	484	484	181	89	Plantation, Senc Natural, Sandakī Natural, unthinned below Sandakī
115	294	35.5	62	4,530	778	5,308	187	1,623	
161	286	47.1	95	11,130	907	12,037	..	..	



FIG 474. Forest of *Picea Morinda*, 8,500 ft , Jaunsar.



FIG 475. Forest of *Picea Morinda* and *Abies Pindrov* opened out by felling, Bashahr.

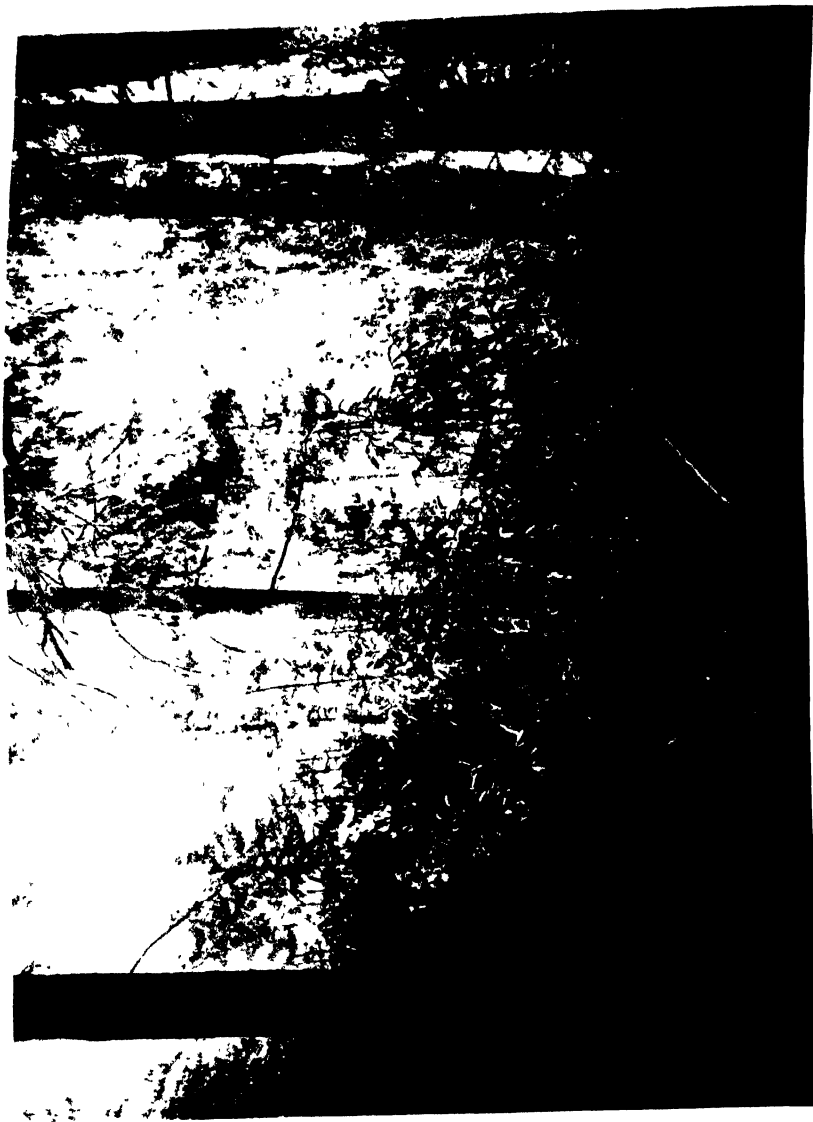


FIG 476. Good natural reproduction of *Picea Morinda* under a light underwood of *Pinus excelsa*, in an area subject to moderate grazing, where the spruce has survived at the expense of the pine, Bashahr.

4. PICEA, Link.

The spruces are tall evergreen trees with needle-like leaves arranged singly in spiral order on small persistent projections along the shoots. Leaves needle-like, tetragonal or flattened in section, persisting for some years. Flowers monoecious. Male flowers solitary in the leaf-axils of the previous year's shoots, with an involucre of scales at the base; female flowers solitary, terminal, erect, on the previous year's shoots. Cones usually pendulous, always so in the Indian species, with persistent scales each bearing two-winged seeds, ripening in one season.

The spruces are divided into two main sections: *Eu-picea*, with leaves quadrangular in section and bearing stomatic lines on all four surfaces, and *Omorica*, with flattened leaves bearing stomata only on their dorsal surface. Henry points out that there are two Indian species: *P. Morinda*, Link, the west Himalayan spruce, belonging to the former section, and *P. spinulosa*, Griffith, the east Himalayan or Sikkim spruce, belonging to the latter.

Species 1. *P. Morinda*, Link; 2. *P. spinulosa*, Griff.

1. *Picea Morinda*, Link. Syn. *P. Smithiana*, Boiss.; *P. Khutrow*, Carr.; *Pinus Smithiana*, Wall.; *P. Khutrow*, Royle; *Abies Smithiana*, Lindl. West Himalayan spruce. Vern. *Rai, re, riar, rau, raiong*, W. Him.; *Tós*, Chamba; *Kachal*, Hazara.

A very tall evergreen tree with a conical crown, horizontal or drooping branches and slender pendulous tassel-like branchlets usually 1-3 ft., but occasionally up to 5 ft. long. Leaves spirally arranged, 1-1.5 in. long, acicular, obscurely quadrangular, with usually two lines of stomata on each of the four sides. Bark grey to greyish brown, exfoliating in small thin rounded scales. Measurements of bark-thickness are given on p. 1151. Wood white, often becoming brown in the centre in large trees, soft to moderately hard, used for planking, shingles, tea-boxes, packing-cases, &c.; has been pronounced very suitable for match manufacture and wood-pulp. Mr. W. Raitt, who has examined the wood for pulping purposes, found that it has a longer fibre than any other spruce hitherto examined. If, as is hoped, the wood proves after impregnation to be suitable for railway sleepers, these should be obtainable in large quantities.

The tree reaches very large dimensions. The following measurements have been recorded near Mundali, Jaunsar, elevation about 8,500 ft.:¹ (1) height 215 ft., girth 19 ft.; (2) height 202 ft., girth 19 ft.; (3) height 195 ft., girth 23 ft.; (4) height 177 ft., girth 20 ft. A tree which I measured in 1907 at Konain, Jaunsar, elevation 7,800 ft., was 202 ft. high and 23 ft. 10 in. in girth; it was growing on the side of a moist ravine on a northerly aspect.

The larger trees very frequently have a mass of brown wood in the centre resembling heart-wood, which often fills the greater portion of the cross-section near the base. This is not true heart-wood, since it extends only a certain distance up the stem, sometimes as much as 25 ft. or more; it is often full of moisture and shows signs of rot, while trees with brown wood tend to become hollow. This brown wood may therefore be regarded as a sign of incipient rot: it greatly reduces the value of the tree. Its formation may

¹ F. Gleadow, Forest School Tour in Jaunsar, 1898-99, p. 49.

commence early : in Bashahr I found two freshly felled trees 4 ft. and 4 ft. 3 in. in girth and ninety-two years of age with brown wood in the centre. This formation of brown wood is a strong reason against growing spruce on a long rotation.

DISTRIBUTION AND HABITAT. This spruce occurs throughout the western Himalaya from Afghanistan eastwards at least as far as Kumaun, chiefly at elevations of 7,000–11,000 ft., though occasionally descending lower and ascending higher. Scattered trees may sometimes be found as low as 5,000 ft. on cool aspects, and under the influence of fire-protection young spruce trees in some localities are making their appearance at elevations lower than those at which mature forests are to be found. Although a gregarious tree it is not often found pure over large areas, but is more commonly mixed with silver fir, or with deodar, blue pine, oak—chiefly *Quercus dilatata*, and at the higher elevations *Q. semecarpifolia*—and other broad-leaved species such as maple, horse-chestnut, walnut, bird-cherry (*Prunus Padus*), elm (*Ulmus Wallichiana*), and others. In some localities the yew is a common underwood species. The spruce stands less heat and requires more moisture than the deodar, and, unlike that tree, does not extend into the drier parts of the inner valleys. On the other hand, although a frequent companion of the silver fir it is capable of thriving on drier ground and in warmer situations than that tree. Some of the finest spruce is found on moist rich soil in association with *Quercus dilatata* of large size. The spruce occurs on various geological formations, perhaps the commonest within its region being mica schist, shale, gneiss, and limestone. Climatically the spruce belongs to the cool, temperate regions of the Himalaya, where there is comparatively heavy snowfall between December and April. The maximum shade temperature probably seldom if ever reaches 90° F., while the rainfall is for the most part between 40 and 100 in., of which the great bulk falls either in the season of the monsoon rain or in the form of winter snow.

Although the spruce forms extensive forests over wide stretches of country its local distribution is at times curiously restricted. Thus in Hazara, although common in the Kagan and upper Siran forests, where silver fir is also common, the spruce is absent in the forests of the Galis, where the silver fir is abundant, except over a very limited area in the Bakot forest, where it grows well. Again, on the Dhaula Dhar of Kangra the spruce and the silver fir occupy separate areas, the former occurring above Palampur and the latter farther west near Dharmsala.

The tall stately trees with their drooping evergreen foliage render the spruce forests sombre in aspect ; the trees themselves are often festooned with the so-called Himalayan Virginia creeper (*Vitis semicordata*), which turns bright red in the autumn. Situated as they usually are on somewhat moist cool slopes, the forests, if closed to grazing, are characterized by a luxuriant undergrowth of shrubs and herbaceous plants ; but as they are much used as summer grazing grounds for sheep, goats, and buffaloes, the ground is often grazed bare. Fig. 474 shows a typical spruce forest closed to grazing ; the climber on some of the trees is *Vitis semicordata*. Fig. 475 shows mixed forest of spruce and silver fir (*Abies Pindrow*) recently opened out by felling.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The needles usually persist



FIG. 477. *Pucca Morinda* FLOWERS AND FRUIT $\times \frac{7}{8}$

- a Male flowers immediately before shedding pollen, April-May b—Male flower after shedding pollen, April-May
 c—Female flower at time of pollination, April-May
 d Female flower (young cone) shortly after pollination, May
 e Ripe cone, Oct.-Nov f Cone scale g—Seed

in full for three to six years, and often persist in part for seven or eight years. They are shed for the most part in the hot season, in May and June. The new shoots, with light green needles, appear in April; the bud-scales adhere in the form of a conical cap which often remains on the tips of the new shoots for a time before falling to the ground.

Male flowers (Fig. 477, *a* and *b*), solitary in the leaf axils towards the end of the previous year's shoots, before ripening ovoid, greenish yellow, 0.5–0.7 in. long by 0.25–0.5 in. in diameter. Anthers in distinct spirals, base surrounded by an involucre of light brown imbricate scales. After shedding their pollen they elongate considerably, and a distinct petiole 0.2–0.3 in. long forms; the flowers become 0.7–1.3 in. long, excluding the petiole, by 0.25 to 0.5 in. broad. The pollen is shed from the latter part of April to the middle of May, according to locality, after which the male flowers fall with their petioles, the cup-like involucre of scales remaining on the tree.

Female flowers and cones. Female flowers (Figs. 477, *c*, and 479) solitary, erect, terminal on the previous year's shoots, at the time of pollination 1.5–1.8 in. long by 0.5–0.7 in. in diameter, cylindrical ovoid, reddish green, with scales in spirals. Scales of two kinds, small membranous bracts and the ovuliferous scales bearing two inverted ovules at their base. Pollination takes place from the latter part of April to the middle of May; at this time the ovuliferous scales are open, their upper parts being bent outwards perpendicular to the axis. Soon after pollination the scales close and fertilization is completed, the young cone increasing in size and weight and becoming pendulous (Figs. 477, *d*, and 480). Subsequent growth is rapid, and by July the cones reach full size though they are still green. They ripen in October and November. The ripe cone (Fig. 477, *e*) is terminal, pendulous, 3–7.5 in. long by 1.5–2 in. in diameter, cylindrical, brown; scales (Fig. 477, *f*) in spirals of 8×5 , broadly ovate with a thin edge and a cuneate base, each subtending two winged seeds. Seed (Fig. 477, *g*) without wing 0.15–0.2 in. long, greyish brown, with wing 0.6–0.8 in. long; wing oblique spatulate, 0.3 in. wide, light brown.

The time taken from the pollination of the female flower to the ripening of the cone is thus about six to seven months, and probable good seed-years can be foretold only so long in advance, the erect female flowers being visible in April or early May at the ends of the branchlets with the aid of field-glasses.

Seeding. Various tests have been carried out recently to ascertain the effect of the age and size of the tree on the production of fertile seed. These are not yet conclusive, but so far they indicate that fertile seed is produced by large and small trees alike. Moderate-sized trees about 3–8 ft. in girth with vigorous well-developed crowns, however, have usually been found to produce cones in greatest abundance. Well-developed cones are often found on trees about twenty years old. The seed retains its vitality, to some extent at least, if stored for a time. Seed kept for eighteen months was tested at Dehra Dun, and showed 25 per cent. of fertility. Tests of fresh seed have shown fertility varying from 22 to 65 per cent.

Good seed-years are the exception rather than the rule. In Jaunsar records for twenty-nine out of thirty-two consecutive years, 1883 to 1914, show good seeding six times, moderate seeding six times, and poor seeding seventeen times. Thus good seeding may be expected only about once every five years.

Many unripe cones are destroyed by nutcrackers (*Nucifraga hemispila*) and by flying squirrels (see under *Pinus excelsa*, p. 1022); the former also extract and devour the seeds from ripening cones.

Pseudo-cones. The flowers and cones of the spruce should not be confounded with the pseudo-cones formed by aphides (*Chermes*). These pseudo-cones are found in the green state about May and June, when they are of various sizes up to 1.3 in. long by 0.6 in. in diameter, ovoid, with pseudo-scales with sharp points (the aborted needles) in regular spirals of 8 × 5. If cut through longitudinally they present the regular appearance of cones, but instead of containing ovules, they contain small chambers in which the minute reddish brown aphides can be seen.

GERMINATION (Fig. 478, *b-g*). Epigeous. The radicle emerges from the end of the seed and descends. The hypocotyl elongates, raising above ground the cotyledons enclosed in the shell of the seed. As the cotyledons elongate the shell remains enclosing their extremities in the form of a cap, eventually falling to the ground, when the whorled cotyledons, eight to ten in number, separate somewhat and the young shoot develops from the centre of the whorl.

THE SEEDLING. The following is a description of the natural forest seedling, grown under average conditions, during the first three years :

First year (Fig. 478, *h*). *Roots* : primary root short, terete, tapering, thin, flexuose, light brown ; lateral roots small or almost absent. *Hypocotyl* distinct from root, 1.5–2 in. long, thin, cylindrical, light green turning brown. *Cotyledons* 8–11, whorled, 0.7–1.1 in. long, acicular, triquetrous, compressed laterally, entire, curved inwards, the whole usually bending to one side, bright green, tender when young, becoming stiffer later. *Stem* (above cotyledons) at most scarcely 0.5 in. long, often consisting of nothing but a tuft of needles and a terminal bud. *Leaves* up to 0.5 in. long, acicular, obscurely quadrangular, minutely and somewhat widely serrulate, with a sharp pointed apex, spirally arranged and situated on small peg-like projections (pulvini). *Terminal winter bud* yellowish grey.

Second year (Fig. 478, *i*). *Roots* : primary root rather short, tapering, wiry, brown ; lateral roots few or moderate in number, short to moderately long. *Hypocotyl* greenish brown, smooth or peeling longitudinally. *Cotyledons* still present, sometimes green, sometimes turning brown by the end of the season. *Stem* : first year's shoot (above cotyledons, if present) with leaves still green, but lower ones often turning yellow or brown ; upper extremity well marked by persistent brown scales of winter bud : second year's shoot pale yellowish grey, somewhat drooping, with spirally arranged leaves 0.4–0.8 in. long, more thickly clustered towards apex, with light brown terminal bud, and on vigorous specimens one or more axillary buds.

Third year (Fig. 478, *j*). *Roots* : primary root not much elongated ; lateral roots moderate in number and length or short. *Hypocotyl* greenish or greyish brown, smooth or peeling longitudinally. *Cotyledons*, if present, dead and falling, their position well marked by a ridge. *Stem* : first year's shoot (above cotyledons, if present) greenish grey, with leaves present or absent, usually brown if present, their raised points of insertion (pulvini) conspicuous ; second year's shoot yellowish grey, leaves present, green or partly yellow and sometimes falling near base ; third year's shoot pale yellowish grey, somewhat drooping, with bright green spirally arranged leaves 0.5–1 in. long, more densely clustered towards apex. *Buds and lateral shoots* : terminal winter bud yellowish grey ; axillary buds usually present at various points on the stem, from which one or more side branches have sometimes developed.



FIG. 478. *Pucca Morinda*— SEEDLING $\times \frac{3}{4}$

a—Seed b-g --Germination stages h Natural seedling at end of first season
i—Natural seedling at end of second season j Natural seedling at end of third season

The season's growth of natural seedlings usually commences about April, and the rate of growth is slow, but it depends much on the amount of light and on the fertility of the soil. Often the growth is not more than about half an inch a year for some years, but under specially favourable conditions, on moist ground with side shade and full overhead light, natural seedlings have been found attaining a height of 1 ft. 4 in. in five years, which, however, is quite exceptional. Under natural conditions an average annual height-growth of about 1 in. for the first five years is usual, the growth thereafter increasing to about 2 to 3 in. per annum for a few years. Thus in counting rings on stumps in natural forest it is necessary to allow at least ten years for the time required for the seedling to attain stump height.

The leaves of seedlings usually persist, in whole or in part, for two or three years. The persistent leaf-cushions, in the form of spirally arranged raised dots after the leaves are shed, are very characteristic of spruce seedlings. The roots are generally short, often attaining a length of only 1 to 2 in. in the first year, and 5 to 6 in. in the third year. For this reason the young plant has little chance of establishing itself in hot, dry situations, but requires a fairly moist soil. It does not, however, persist under heavy shade, and the ideal conditions for its growth are abundance of overhead light combined with side protection from the desiccating effect of the sun. Although sensitive to drought the seedling is frost-hardy in its natural home.

Nursery-raised seedlings, as might be expected, grow more vigorously than natural seedlings under average conditions, but their growth is also comparatively slow, a yearly average of only about 2 to 3 in. in height being attained during the first few years. A height of 4 ft. in ten years is above rather than below the average even for artificially raised seedlings, but thereafter growth is more rapid.

SILVICULTURAL CHARACTERS. The spruce is a moderate light-demander, ranking more or less equally with the deodar in this respect. In early youth it requires protection from the sun, and stands a certain amount of shade, but once established its growth is most vigorous when it obtains complete overhead light, and under shade which is at all heavy it becomes suppressed. The root-system is spreading, somewhat superficial and not very massive, and the tree is not wind-firm. The spruce is not so subject to snow-break as the blue pine or the deodar, owing chiefly to its more pendulous branches and branchlets. Saplings, however, are frequently bent down by sliding snow, and as a result curvature at the base may persist throughout the life of the tree; the risk of this form of damage is aggravated where the saplings are isolated, and hence growing in dense crops is beneficial, while unnecessary removal of surrounding growth and undergrowth should be avoided. Fire does not ordinarily occur in spruce forests, but when it does the spruce suffers more than any of the other west Himalayan conifers except the silver fir. Young spruce plants are less subject to damage from browsing than young blue pine plants; goats, it is true, browse on the young shoots, but if other fodder is plentiful they usually avoid spruce. In grazed areas, however, great damage is done to spruce seedlings owing to their small size, for the plants are readily destroyed by trampling and by being uprooted along with grass and other herbage.

No dangerous fungus attacks have yet been reported in spruce areas. *Trametes Pini* has been found on lopped spruce in Kulu, but it does not appear to be the scourge which it is in the case of *Pinus excelsa*. *Peridermium Thomsoni*, Barcl., is the aecidial stage of a fungus which attacks the needles, causing them to become swollen and curled and to burst open and emit orange-coloured spores in May and June, at which time evidence of the attack can be seen in the form of long orange-coloured tassels sometimes over a foot long. The same fungus also attacks green cones, the scales becoming soft and swollen and covered with orange flecks. This fungus does not appear to be very common. I have found it locally common in Kulu. *Barclayella deformans*, Dietel, is the teleuto stage of the same fungus, and is much commoner;¹ it produces short orange tassels 1-2 in. long, the needles being less swollen than in the case of *Peridermium Thomsoni*. The spores ripen in May and June. *Peridermium Piceae*, Barcl., is another rust, recorded by Mr. Oliver from Jaunsar, of which only the aecidial stage is known.² The young shoots are attacked, long narrow spore-cases appearing somewhat irregularly along the upper surface of the affected needles, which turn yellow. Regarding this fungus, Dr. Butler says: 'Mr. Oliver informed me that he had seen trees in Chakrata Cantonment in 1902 dying or dead from the effects of this fungus. This was due to the loss of all infected needles in 1901, when the attack was very severe. The trees were so weakened in consequence that they were unable to make new shoots or only put out feeble ones.'

NATURAL REPRODUCTION. The natural reproduction of the spruce is handicapped to some extent by the comparatively long intervals at which good seed-years take place. So far as is known the best seed-bearers, that is, those producing the largest quantity of well-developed cones, are trees of moderate size, not those of very large size. Under natural conditions germination begins about the end of May or during June, and may continue during July, August, and part of September.

The chief requirements for successful natural reproduction are a germinating bed consisting of recently exposed mineral soil, which should be porous and fresh, protection from fire and grazing, freedom from troublesome weeds, protection in the earlier stages from the desiccating effect of the sun, and an abundance of overhead light. Spruce seedlings often spring up in abundance on mineral soil exposed by small landslips and road cuttings and on abandoned cultivation. A thick accumulation of dead needles is decidedly unfavourable, since the young seedling does not produce a long taproot, and readily dies of drought if the root is unable to penetrate quickly to the mineral soil; the adverse effect of raw humus, which may possibly be due to chemical as well as to physical action, is seen in the difficulty which spruce reproduction experiences in establishing itself under a parent crop of spruce. Young spruce has considerable power of penetrating a moderate growth of weeds, but where the weed-growth is dense and matted, as in the case of *Strobilanthes Wallichii*, the seedlings are unable to establish themselves. As in the case of the blue pine, spruce reproduction is favoured by the presence of *Indigofera*, *Desmodium*, and bracken.

Grazing is fatal to the establishment of seedlings in their earlier stages,

¹ E. J. Butler, Ind. Forester, xxxi (1905), p. 611.

² Butler, loc. cit., p. 614.

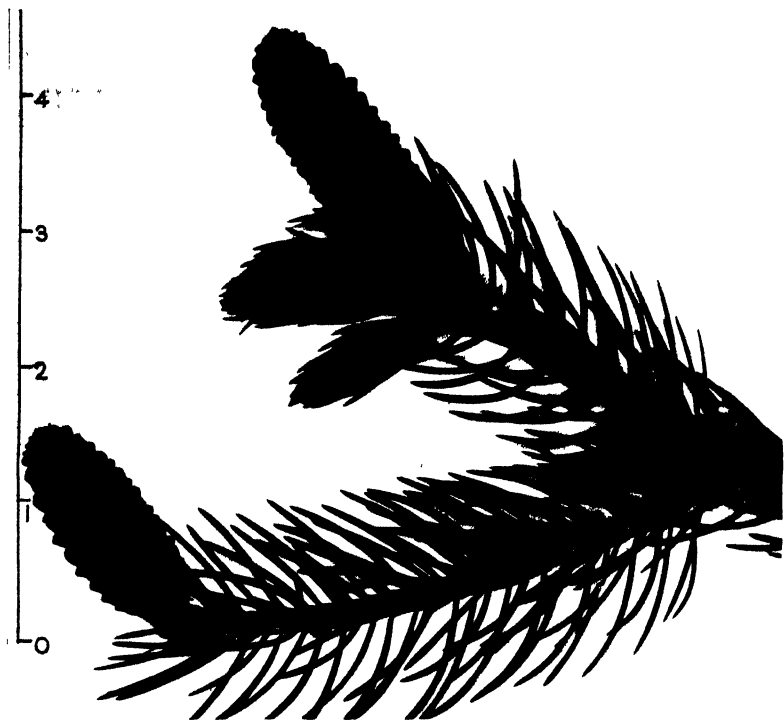


FIG. 479. *Picea Morinda*, female flowers at time of pollination, May.
Scale shows inches



FIG. 480. *Picea Morinda*, young cones shortly after pollination, end of May.
Scale shows inches.

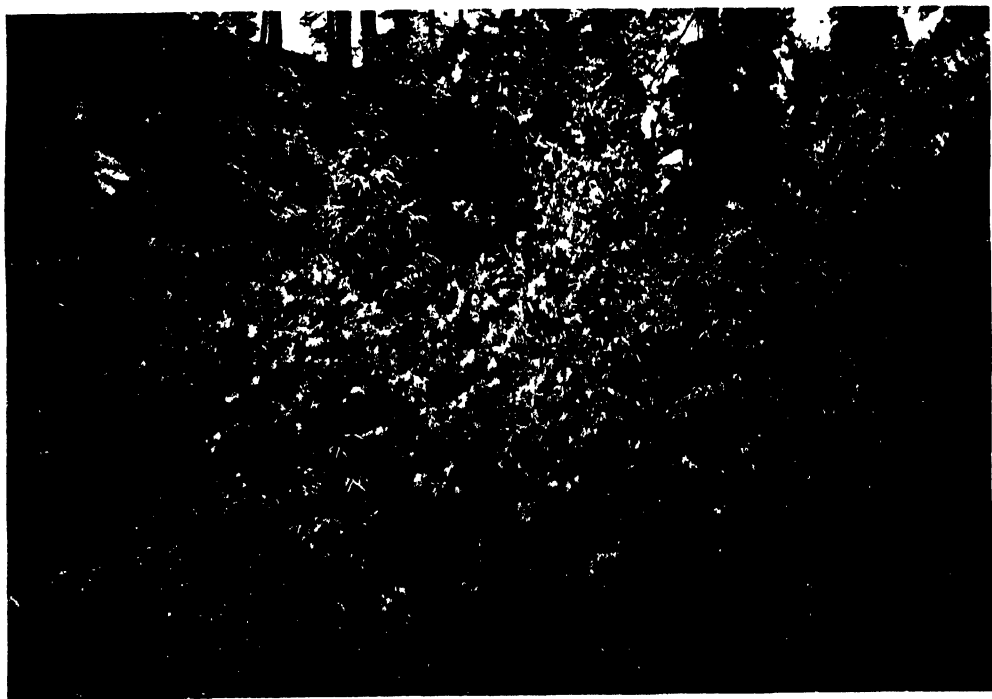


FIG. 481. Good natural reproduction of *Picea Morinda* and *Pinus excelsa* in a large gap with much shrubby undergrowth affording protection from browsing, Bashahr.



FIG. 482. Dense natural reproduction of *Picea Morinda*, *Abies Pindrow*, and *Quercus semecarpifolia* on an open strip receiving lateral shade from the south-east, Kulu.

since owing to their small size they are easily destroyed by trampling or are easily uprooted. Goat browsing is particularly harmful, as the young plants are eaten by these animals. Nevertheless if the young spruce is able to survive the first few years by reason of the protection afforded by bushes, it has a better chance of ultimate establishment than the blue pine, which is more readily browsed. Fig. 476 shows a dense mass of spruce reproduction establishing itself, owing to the protection of bushes, under a light overwood of blue pine and spruce in an area open to moderate grazing; blue pine reproduction is kept back by the grazing, whereas the young spruce is establishing itself successfully in spite of it. As in the case of the deodar, the thorough clearing of the ground by means of fire has a beneficial effect on spruce reproduction. In the Surd forest of the Nogli range, Bashahr, an excellent young crop of spruce, mixed with blue pine, has established itself on an area overrun by a severe fire many years ago. In regenerative operations fire will no doubt be found to play an important part in inducing spruce reproduction by consuming debris and raw humus and bringing the soil into a suitable condition; mere opening out of the canopy too often results in the appearance of a heavy growth of weeds.

The question of light is a most important one in connexion with spruce reproduction. The best reproduction is usually found in open gaps where complete overhead light is obtained, though it also appears readily under a light overwood of blue pine. Spruce regeneration is often excellent in mixture with that of the blue pine, the conditions favourable to the one being to a large extent favourable to the other (see Fig. 481). In moist ravines and cold, damp situations it is usually scarce or absent, as is also the case in ravines scoured by snow-slides.

The question of side shade in early youth is one which requires further study. Wagner has demonstrated the value of side shade from the morning sun in the case of the European spruce, and so far as observations have been made its beneficial effects, in preventing desiccation, are no less apparent in the case of the Himalayan spruce, though observations are as yet incomplete. The following cases may be cited:

1. In the late autumn of 1909 four experimental plots were laid out near Mundali in Jaunsar, in an open area subject to grazing, on which there were two belts of spruce forest giving lateral shade to part of the area. The slope was moderate, and the aspect varied from west to north. Two of the plots were fenced and two were left open to grazing, while in one of each pair the soil was hoed up, the other being left unhoed. Throughout the fenced area, and in the hoed portion of the grazed area, spruce seed was sown. These plots were inspected in the autumn of 1914, that is, five years after being laid out, and the following observations were recorded:

(i) Under cover of the spruce belts there was a dense growth of *Strobilanthes* and no young spruce; (ii) in the open, but with complete lateral shade from the morning and midday sun, i. e. from east to south, the soil was moist and spruce seedlings were plentiful, in the fenced plot attaining a height of 1 ft. 4 in., with vigorous growth, and in the unfenced plot attaining a height of 5 in. and much browsed; (iii) in the open, with protection from the morning sun but not from the midday sun, spruce seedlings were not plentiful, and

attained a maximum height of only 5 in., even when protected from grazing ; (iv) in all portions exposed to the sun throughout the day the ground was dry, herbaceous weeds had died down by October, and spruce seedlings were absent ; (v) a moderate growth of weeds was found to act as a protection, but a dense growth of *Strobilanthes* prevented the survival of any seedlings ; (vi) closure to grazing proved decidedly beneficial ; (vii) spruce seedlings were more plentiful and more vigorous in the hoed than in the unhoed areas, but as the former were also the areas best protected from the sun, no conclusion can be based on this.

2. Mr. Marsden has furnished me with the following note recorded in May 1915 in the Kundi forest, Chamba, at an elevation of 6,950 ft. : ' A small gap in mixed deodar, spruce, and blue pine forest shows good spruce regeneration of all ages up to 20 ft. high where there is shelter from north-east round to south, but nothing on the other sides ; it extends about 80 ft. into the gap and no more.'

3. In Kulu in June 1914, at an elevation of 9,000 ft., a cleared strip about 20 yds. wide on a northerly aspect, protected laterally on the south-east by a mature crop of spruce, silver fir, and brown oak (*Quercus semecarpifolia*), had filled up with a dense mass of natural reproduction of these three species, as shown in Fig. 482. The origin of the cleared strip could not be traced ; the clearing, which may have been due to an abnormal snow-slide or to wind, had evidently been made at least fifteen to twenty years previously.

These instances serve to indicate that protection from the morning and midday sun is beneficial to the establishment of spruce reproduction, though further experiments and observations are required to determine this definitely.

ARTIFICIAL REPRODUCTION. The spruce has not been grown artificially to any extent in the Himalaya, but where it has been grown transplanting from the nursery has usually proved more successful than direct sowing. Fresh seed should be sown in the nursery in October or November. Germination commences towards the end of the following May or in June and continues during July and August. The seedlings may be pricked out in the nursery when two years old and planted out at an age of three or four years ; some plantations in Jaunsar, however, have been formed with plants two years old. Care is necessary during transplanting not to injure the roots or to expose them to the sun, for which reason the young plants, when removed from the nursery to the planting site, should be bundled together with their roots wrapped round with damp moss.

SILVICULTURAL TREATMENT. The spruce has hitherto been worked as a rule under selection fellings, but, as in the case of the deodar, this system has proved unsuitable, since the spruce is not sufficiently shade-bearing for such treatment. The most suitable method of regenerating the spruce naturally under different conditions requires further study. The factors influencing natural reproduction have been dealt with above, and it may be agreed that some form of opening of the canopy, combined where necessary with cutting and burning undergrowth and collecting and burning felling refuse in good seed-years, as in the case of the deodar (see p. 1122), should effect reproduction in most cases.

Some good examples of spruce reproduction appearing as a result of an

even spacing of the canopy are to be found in Kulu and Bashahr. The trees retained as seed-bearers should be of moderate size, large over-mature trees being felled. In Kulu a spruce crop between fifty and sixty years of age, the trees having a mean girth of about $3\frac{1}{2}$ ft., was opened out heavily in 1912 in order to introduce deodar by line sowings; the trees of the overwood were spaced about 50 ft. apart, giving seventeen trees per acre, and the result after two years was a plentiful crop of young spruce seedlings, the appearance of which was no doubt helped by the working of the soil in order to sow deodar. Where seed-bearers exist there is little difficulty in regenerating spruce along with blue pine, and some good examples of such mixed young crops, often with deodar, are to be found in the Nogli range of Bashahr as a result of an even spacing of seed-bearers, about five to twenty to the acre (see Figs. 457 and 458). In such areas some of the best reproduction is to be found where the majority of the seed-bearers are about $4\frac{1}{2}$ to 6 ft. in girth.

The instances already given of the beneficial effect of side shade from the morning and to some extent from the midday sun indicate that where desiccation is feared there may be scope for working by means of strip fellings proceeding from north-west to south-east. Such fellings have not yet been tried in practice. The best regeneration period for the spruce under different conditions remains to be ascertained by experience. A period of thirty years is proposed tentatively for the future working of the forests both in Hazara and in Kulu.

The tending of spruce crops is a matter to which little attention has so far been given. In its natural condition the spruce is capable of forming very dense crops, and in such a condition produces clean timber. The correct method of tending such crops would appear to be to keep them dense, thinning them regularly but with caution, as in the case of the European spruce.

STATISTICAL. 1. *Bark thickness.* Numerous measurements in Jaunsar gave the following average bark thickness for different girths :

Girth.	Bark thickness.	Girth.	Bark thickness.
ft.	in.	ft.	in.
1-2	0.3	5-6	0.8
2-3	0.45	6-7	0.9
3-4	0.6	Over 7	1.0
4-5	0.7	..	..

2. *Growth in youth.* Measurements made at different times in thirteen young plantations in Jaunsar showed the following mean growth in girth and height :

Age.	Mean girth.	Mean height.
years (from seed).	in.	ft.
8	2.8	2.8
10	3.3	3.5
12	3.9	4.3
14	4.6	5.3
16	5.4	6.5
18	..	7.8
20	..	9.5

3. *Girth and height increment.* The statement below, showing the rate of growth in girth and height, has been compiled from such data as are available. In order to obtain uniform figures for comparison, nothing has been added

for the time taken for a seedling to establish itself, while in each case the means have been determined from curves plotted by the aid of rectangular co-ordinates. The girth includes bark in each case.

Picea Morinda : rate of growth in girth and height.

Age.	Mean girth.				Jaunsar.		Kashmir.	Mean height.
	Inner Saraaj (18 trees).	Outer Saraaj (36 trees).	Kulu (33 trees).	Rupi (34 trees).	Konain, alt. 7,800 ft. ²	General average. ³	Batot range. ⁴	Jaunsar. ³
years.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft.
20	1 9	1 7	1 2	1 8	1 11	1 2	0 10	18
40	3 6	3 3	2 4	3 3	3 10	2 8	1 10	39
60	5 5	4 7	3 5	4 8	5 7	3 11	2 9	56
80	7 4	5 10	4 4	6 1	6 11	5 1	3 9	73
100	9 1	7 0	5 2	7 6	8 1	6 1	4 9	89
120	..	8 2	6 0	..	..	7 1	5 9	105
140	..	..	6 10	..	..	..	6 10	..
160	..	..	7 8	..	..	..	7 11	..
180	..	..	..	..	..	..	9 2	..

In order to allow for the time taken for a seedling to establish itself, at least ten years should be added to the age in each case.

Ring-countings in the Kotkhai-Kotguru forests of the Simla hills showed an average of 11.5 rings per inch of radius, giving a mean annual girth increment of 0.55 in.⁵ In the working plan for the Kulu forests¹ the spruce is estimated to attain on an average a diameter of 2 ft., or a girth of 6 ft. 3 in., in 100 years, after which the rate of growth diminishes rapidly. In the leased forests of Tehri Garhwal it is estimated to reach a girth of 6 ft. in 122 years.⁶

4. *Volume production.* No comprehensive general statistics of volume production are yet available for the spruce. Perhaps the most complete local yield table yet compiled is the combined yield table for the silver fir and spruce recently prepared by Mr. C. G. Trevor in Kulu and given under *Abies Pindrow* (see p. 1141). Except in the case of young trees, representative average figures giving the volume of utilizable timber are often difficult to compile with any degree of accuracy owing to the frequent presence, in varying quantity, of decayed wood in the centre of the bole. For this reason the yield of scantlings from trees of the same size may vary enormously, although the form of the bole is more constant than in the case of most species. This point is illustrated by the following results of detailed measurements of twelve spruce trees felled in Jaunsar in 1914 with the idea of forming a rough preliminary idea of the probable yield of timber suitable for match manufacture in fully stocked crops :

¹ Working Plan for the Kulu Forests, Punjab, C. P. Fisher, 1898.

² Ring-countings by J. Donald, 1913.

³ Working Plan for the Jaunsar-Bawar Forests, P. H. Clutterbuck, 1901.

⁴ Working Plan for the Batot Range Forests, Riasi Division, Kashmir, Hans Raj, 1917 (these measurements include both spruce and silver fir).

⁵ Working Plan for the Kotkhai-Kotguru Forests, Simla Division, E. M. Coventry, 1903.

⁶ Working Plan for the Leased Deodar Forests, Tehri Garhwal, J. C. Tulloch, 1907.

Picea Morinda : measurements of individual trees, Jaunsar, 1914.

No.	Age. ¹ years.	Girth at breast height.		Total height. ft.	Solid volume per tree.						Estimated number of trees per acre in fully stocked crop.	Estimated * volume of utilizable match-wood per acre in fully stocked crop.
		ft. in.	ft.		Gross volume of bole down to 24 in. girth (bark excluded from volume). cub. ft.	Estimated volume of brown or rotten wood. cub. ft.	Utilizable timber after deducting rotten or dark wood (bark ex- cluded). cub. ft.	Top piece down to 6 in. girth (bark included). cub. ft.	Utilizable match-wood down to 3½ ft. girth, after deducting dark wood (bark excluded). cub. ft.			
1	175	6 10	145	148	82	66	2	54	90	4,840		
2	185	7 5	151	199	121	78	1	66	76	5,016		
3	165	6 4	153	144	39	105	3	91	99	9,609		
4	120	5 0	125	65	21	44	3	25	222	5,550		
5	125	5 0	132	70	23	47	2	23	222	5,106		
6	180	6 3	126	108	58	50	3	39	109	4,251		
7	180	5 4	124	83	25	58	1	38	134	5,092		
8	200	5 11	141	115	58	57	2	39	121	4,719		
9	106	4 1	100	42	1	41	3	22	360	2,920		
10	101	4 8	94	48	5	43	3	30	302	9,060		
11	160	5 3	125	83	25	58	3	38	134	5,092		
12	97	5 1	86	46	8	38	3	26	194	5,044		

The trees selected for measurement were felled in well-stocked, even-aged crops, and were typical stems of average growth ; the number of trees per acre was estimated from the average spacing of trees in such crops. It is interesting to note the results obtained by plotting the figures in the above statement by rectangular co-ordinates and constructing a mean curve. These results are tabulated in the following statement, which must be taken to be nothing more than a very rough preliminary estimate based on a few measurements only :

Picea Morinda : estimated out-turn of match-wood in well-stocked, even-aged crops, Jaunsar.

Age. years.	Girth at breast height.		Volume of utilizable match-wood per acre. cub. ft.	Mean annual increment of utilizable match-wood per acre. cub. ft.
	ft. in.			
90	4 4		5,000	55
100	4 7		7,800	78
110	4 10		7,400	67
120	5 1		5,900	49
130	5 4		5,500	42
140	5 7		5,200	37
150	5 10		5,100	34
160	6 0		5,000	31
170	6 2		4,900	29
180	6 4		4,850	27
190	6 6		4,800	25
200	6 8		4,750	24

* From this it would appear that the mean annual increment per acre for utilizable match-wood culminates at about one hundred years, the corresponding girth being roughly 4½ ft.

¹ Ten years added for time taken for establishment of seedling.

The Kulu working plan, 1898, gives the following out-turn figures based on measurements of over 100 trees :

Girth of tree at $4\frac{1}{2}$ ft. from ground.	Volume in the round.
ft.	cub. ft.
6-6 $\frac{1}{2}$	93
6 $\frac{1}{2}$ -7 $\frac{1}{4}$	121
7 $\frac{1}{4}$ -8 $\frac{1}{2}$	154

The average out-turn in sawn scantlings from 14 spruce and silver fir trees 2-2 $\frac{1}{2}$ ft. in diameter in the Dalhousie range forests was 57 cubic ft.¹

2. *Picea spinulosa*, Griff. Syn. *P. morindoides*, Rehder. East Himalayan or Sikkim spruce. Vern. *Sehshing*, Bhutia.

A tall evergreen tree attaining a height of over 200 ft. The spruce of the eastern Himalaya was until comparatively recently considered to be identical with the west Himalayan spruce, *P. Morinda*, Link. Henry² points out, however, that it is not only a separate species but belongs to a different section of *Picea*. The following is taken from his description of the tree :

'Bark rough and scaling off in small quadrangular plates. Young branchlets slender, glabrous, yellowish grey. . . . Leaves, in an imperfect radial arrangement, covering in closely imbricated ranks the upper side of the branchlets, those on the lateral sides directed outwards and forwards, those on the under side pointing downwards and forwards ; $\frac{3}{4}$ to 1 $\frac{1}{4}$ in. long, $\frac{1}{10}$ in. broad, slender, acute at the apex, which is tipped with a sharp point ; flattened but keeled on both surfaces, so that the section is rhomboid-elliptic ; ventral surface green without stomatic lines and directed towards the light ; dorsal surface with two stomatic bands, each of four to six lines. . . .

'Staminate flowers pink, $\frac{3}{4}$ in. long. . . . Cones about 2 $\frac{1}{2}$ in. to 3 in. long on cultivated trees, up to 4 in. long on wild trees, 1 to 1 $\frac{1}{4}$ in. in diameter, cylindrical, obtuse at the apex, green with a purple border to the scales when growing, shining brown when mature ; scales thin and flexible, suborbicular with a cuneate base, about $\frac{1}{2}$ to $\frac{5}{8}$ in. wide, bevelled in the upper margin, which is rounded (in some wild specimens truncate), entire, undulate or slightly denticulate ; bract ovate, acute, $\frac{1}{6}$ in. long. Seed $\frac{1}{8}$ in. long, greyish brown ; seed with wing $\frac{1}{2}$ in. long ; wing broadest above the middle, rounded or denticulate at the apex.'

The tree is indigenous to Sikkim and Bhutan in the inner valleys at 8,000 ft. and over, and has been recorded from the Chumbi valley at 9,000-10,000 ft. In Sikkim it occurs with *Tsuga Brunoniana* at 8,000-11,000 ft., with *Abies Webbiana* at 9,000-11,000 ft., and sometimes with *Larix Griffithii*. In Bhutan it is commonest at 9,000-11,000 ft., and is often associated with *Pinus excelsa* at the lower elevations. Mr. W. R. Jacob³ says that in Bhutan extensive areas of spruce and blue pine forest have been cleared away permanently, but where sufficient seed-bearing trees are left in the vicinity the ground is again covered with young trees in a remarkably short space of time.

The size to which the tree grows under favourable conditions may be gathered from the following account of it by Elwes :⁴ 'Though I saw this tree in the Lachen valley of Sikkim during my first journey to the Tibetan

¹ Revised Working Plan for the Dalhousie Range Forests, Chamba, R. McIntosh, 1913.

² Elwes and Henry, *The Trees of Great Britain and Ireland*, vi. 1392.

³ Report on the Forests of Bhutan, 1912, para. 25.

⁴ Elwes and Henry, *op. cit.*, vi. 1393.



FIG 483 *Tsuga Brunonianana* at 9,400 ft Darjeeling.

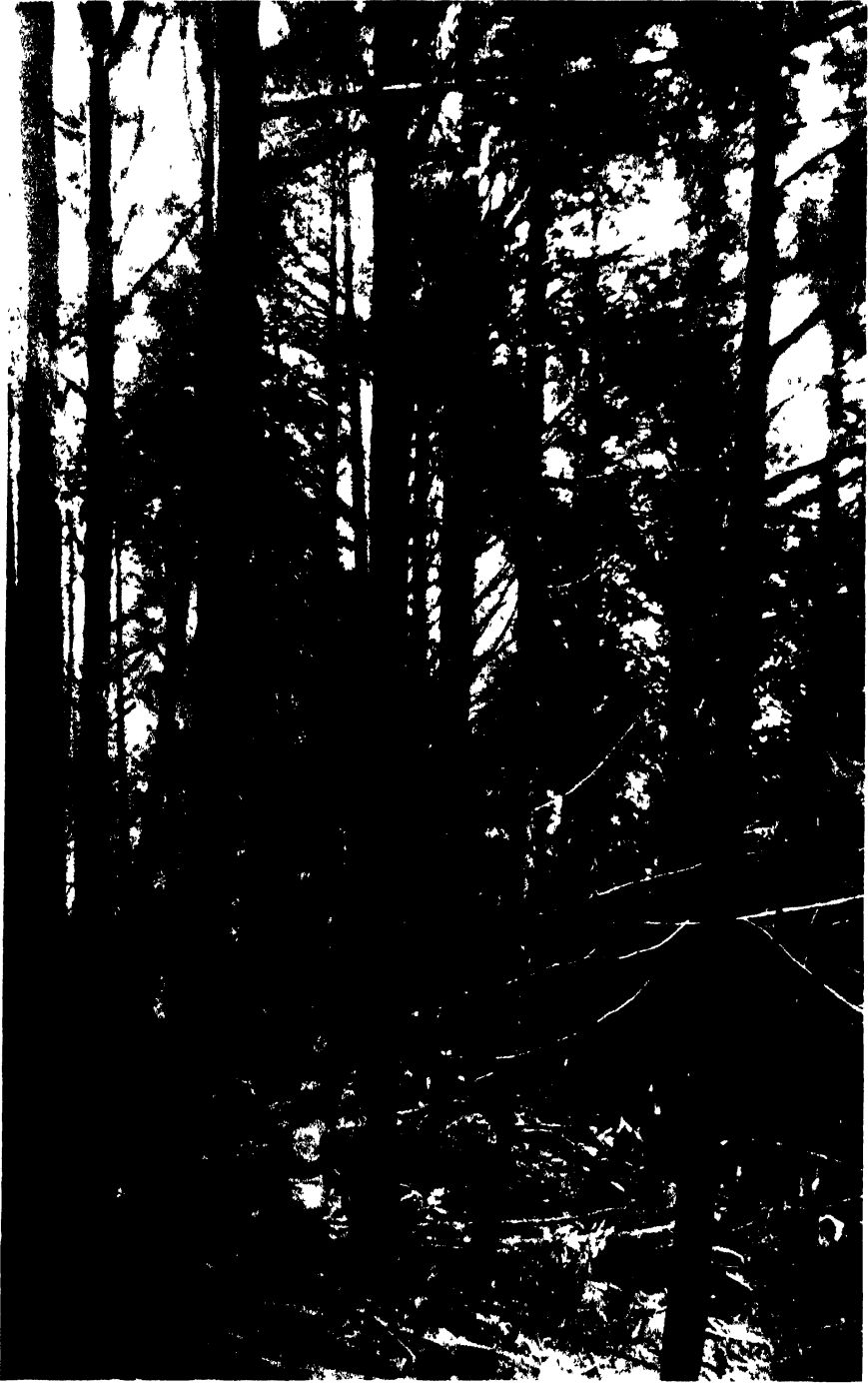


FIG. 484 *Tsuga Brunoniana*, pole forest recently thinned, Darjeeling

frontier in 1870, I did not take special notice of it at the time, and certainly saw no such wonderful trees as are described by Mr. J. Claude White in his recently published book.¹ These grow in the Sebu valley, a tributary of the Lachung, and must be among the tallest trees in India. Mr. White says : " One fallen giant, a spruce that I measured, was 220 ft. from the roots to where it had broken off short, and there it measured 6 ft. in girth. What had become of the top I do not know, but it was a magnificent specimen."

'To confirm this, I may say that I have since heard from Mr. A. D. Hickley, who visited and remeasured the same tree. He informs me that it grew at a place called Chu-par-rab-dong on the left bank of the river just opposite Yakchi, at an elevation of about 10,000 ft. Five lengths of the fallen stem were missing, having been probably used by the natives ; but without counting these he made the length 207 ft., and the girth as follows : at the base, 12 ft. 7 in. ; at 50 ft., 13 ft. ; at 100 ft., 12 ft. ; at 139 ft. (the place where the tree was first broken in its fall), 9 ft. 4½ in. The thinnest piece, without the bark, was 5 ft. 2 in. in girth. In the same valley not far away, Mr. Hickley measured another spruce, also with the top broken, 197 ft. long ; and there were many like it still standing.'

5. TSUGA, Carrière.

The hemlock spruces are evergreen trees with horizontal or pendulous branches and pectinately arranged leaves. The leaves persist for some years, and the foliage is dense in consequence. Flowers monoecious. Male flowers in the axils of the previous year's leaves ; female flowers terminal on the previous year's lateral shoots. Cones small, with persistent scales, ripening in one season. One Indian species.

Tsuga Brunoniana, Carr. Syn. *Pinus Brunoniana*, Wall. ; *Abies dumosa*, Loudon. Himalayan hemlock spruce. Vern. *Tengre salla*, Nep. ; *Tangshing*, Bhutia.

A large, handsome evergreen tree with a pyramidal outline and spreading branches which droop gracefully. Leaves 0·5–1 in. long, linear, distichous, dark green and grooved above, silvery white beneath. Bark thick, rough. Wood whitish, soft, not of very good quality, used for shingles. In Sikkim the bark is used for roofing. The tree ordinarily attains a height of 100 to 120 ft. and a large girth. Trees up to 170 ft. in height have been recorded, and Mr. E. Marsden in 1917 measured a tree 17 ft. 9 in. in girth in the Singalila range, Darjeeling.

DISTRIBUTION AND HABITAT. Central and eastern Himalaya from Kumaun to Bhutan, chiefly at 8,000–10,000 ft., but ascending to about 11,000 ft. and descending to 6,500 ft. Duthie² says it forms beautiful forests near Sosa in north-eastern Kumaun at 9,000–10,000 ft. Gamble says that in British Sikkim it is found in the Siri valley mixed with or just below the silver fir (*Abies Webbia*), and associated with yew, oaks (especially *Quercus pachyphylla*), rhododendrons, and the *malin* bamboo (*Arundinaria racemosa*).

On the Singalila and Chola ranges it occurs at 8,000–11,000 ft., sometimes with *Picea spinulosa*, *Abies Webbia*, or *Larix Griffithii*. Fig. 483 shows a group of old trees, and Fig. 484 a pole crop.

¹ Sikkim and Bhutan, p. 79 (1909).

² Gard. Chron., Mar. 1886.

year for some years, but occasionally they elongate and become long shoots or produce flowers. Flowers monoecious. Cones erect, with persistent imbricated woody scales ; seeds winged. One Indian species.

Larix Griffithii, Hook. f. and Thoms. Sikkim larch. Vern. *Sah, saar*, Lepcha ; *Boargasella*, Nep.

A moderate-sized or large deciduous tree with a pyramidal shape and long pendulous branches. Needles light green, 1-1.3 in. long. Bark brown. Wood soft to moderately hard with a red heart-wood, durable.

The tree is generally said to reach a height of 60 ft., but Elwes¹ mentions that Mr. Hickley measured one growing between two spruces in the Sebu valley, a tributary of the Lachung, with a height of well over 125 ft., which is much taller than any previously recorded. Trees found in eastern Nepal by Sir Joseph Hooker in 1848 were only 20 to 40 ft. high.²

DISTRIBUTION AND HABITAT. As far as is known the tree has only a limited distribution in the Himalaya in eastern Nepal, Sikkim, and Bhutan at 8,000-12,000 ft., but commonest from 9,500 to 11,000 ft. Also in the Chumbi valley, Tibet. In Bhutan it is often mixed with *Pinus excelsa*, or forms pure forests above it, or occurs in small groups, frequently with an undergrowth of rhododendron. It is sometimes associated with *Abies Webbiana*, *Picea spinulosa*, or *Tsuga Brunoniana*. It does not appear to be found in British Sikkim. Hooker says it attains a height of 60 ft. in deep valleys, but prefers the dry rocky ancient moraines formed by glaciers, and also grows on grassy slopes where the drainage is good. This corresponds exactly to the habit of the European larch (*L. europaea*, DC.) in the Alps ; this tree is found on well-drained grassy slopes, and regenerates freely in pure crops on fresh debris in the open, particularly on the taluses formed at the base of precipices, on new ground exposed by landslips or snow-slides, or on the diluvial cones formed by mountain torrents where they issue into the valleys.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The needles are shed in the autumn, the new foliage appearing in the spring. The flowers appear in May and the cones ripen in October the same year (Brandis). Cones cylindrical, 2-3 in. long or more, with persistent scales, erect (reversed) on the pendulous branchlets ; seeds winged, in pairs on each scale, 0.4-0.5 in. long including the wing.

RATE OF GROWTH. A specimen from the Chumbi valley, Tibet, examined by Mr. Gamble, showed 21 rings per inch of radius, giving a mean annual girth increment of 0.29 in., which is slow.

7. CUPRESSUS, Linn.

The cypresses are evergreen trees with small scale-like, opposite, closely adpressed leaves ; primordial leaves, as in seedlings, needle-like, spreading, in whorls of three or four. Flowers monoecious, terminal on the ultimate branchlets. Male flowers cylindrical, with numerous decussate peltate stamens. Female cones with decussate scales which become peltate and woody on maturing. Seeds small, compressed, winged.

The only indigenous species is *C. torulosa*, Don, but other species are

¹ Elwes and Henry, *op. cit.*, vi. 1394.

² Him. Journ., i. 255.

occasionally cultivated in India. *C. cashmeriana*, Royle, *ex* Carrière, is possibly a form of *C. torulosa*.

Species 1. *C. torulosa*, Don; 2. *C. sempervirens*, Linn.; 3. *C. funebris*, Endl.; 4. *C. macrocarpa*, Hartweg; 5. *C. lusitanica*, Miller; 6. *C. Lawsoniana*, Murray.

1. *Cupressus torulosa*, Don. Himalayan cypress. Vern. *Devidiar*, *galla leori*, *surai*, *raisal*, W. Him.

A large evergreen tree with a pyramidal crown; branches ascending, horizontal or drooping, curving markedly upwards towards the ends. Leaves triangular, closely imbricate (Fig. 486, e). Bark greyish brown, peeling off in narrow, longitudinal strips, often running somewhat spirally up the tree from left to right. Wood moderately hard; heart-wood light brown, fragrant, of excellent quality and very durable. If the tree were commoner it would be an important timber tree; it is, however, so local that the timber is unobtainable in any quantity. The wood is used chiefly for building, often for temples: it is also burnt as incense.

The tree reaches large dimensions. In the vicinity of the Deota temple, Tehri Garhwal, two trees were measured in 1885 and found to be (1) 155 ft. in height and 23 ft. 6 in. in girth, (2) 140 ft. in height and 24 ft. in girth.¹ At Naig, south of Lobha, Stewart records one 27 ft. in girth near the ground.

DISTRIBUTION AND HABITAT. Outer ranges of the western Himalaya at 6,000–9,000 ft., from Chamba to Nepal. The tree is decidedly local in its distribution, occurring in patches of varying extent, sometimes pure, sometimes associated with deodar, spruce, silver fir, blue pine, or oaks. Among localities where the cypress is found wild may be mentioned the slopes of China hill at Naini Tal, on shale but not far from limestone, in Jaunsar on the limestone cliffs of Moila and Lokandi, at 8,000–9,000 ft., and below Karamba peak, in the Simla hills on the Shali and Tikka ridge on limestone and in the Simla catchment area on shale, as well as in various localities in Chamba, Kulu, Garhwal, Kumaun, and other parts of the western Himalaya. There is a fine group of cypress trees on the ridge above Bamsu village in Tehri Garhwal. The tree is found commonly on limestone, though occasionally on other rocks. Fig. 485 shows its typical occurrence on limestone cliffs; in such places it has a remarkable capacity for growing on the sides of sheer precipices, sending its roots into the crevices, the stem growing vertically parallel to the side of the precipice. Within its habitat it is sometimes found on hot, dry slopes where few other species will grow.

Although in its wild state it is found principally on limestone, the tree is by no means particular as to soil or climate. It is frequently planted in the Himalaya on various rock formations and soils, and grows well in many other parts of India. At Dehra Dun (2,000 ft.) it grows rapidly and attains very fair dimensions on deep loam. It is grown in various stations on the plains, including Saharanpur, Calcutta, and some of the plains stations of the Punjab, where, if irrigated, it stands a shade temperature of 120° F. It is grown in some parts of the Indian Peninsula, at Poona, at Chikalda in Berar at 3,000 ft., and in the Nilgiris at about 7,000–8,000 ft. It has shown much promise in the Sanniyasimalai plantation in North Salem, where it has recently been planted to a considerable extent. In its natural habitat the absolute maximum shade

¹ Notes on Sowing, Planting, &c., in Jaunsar, 1885.

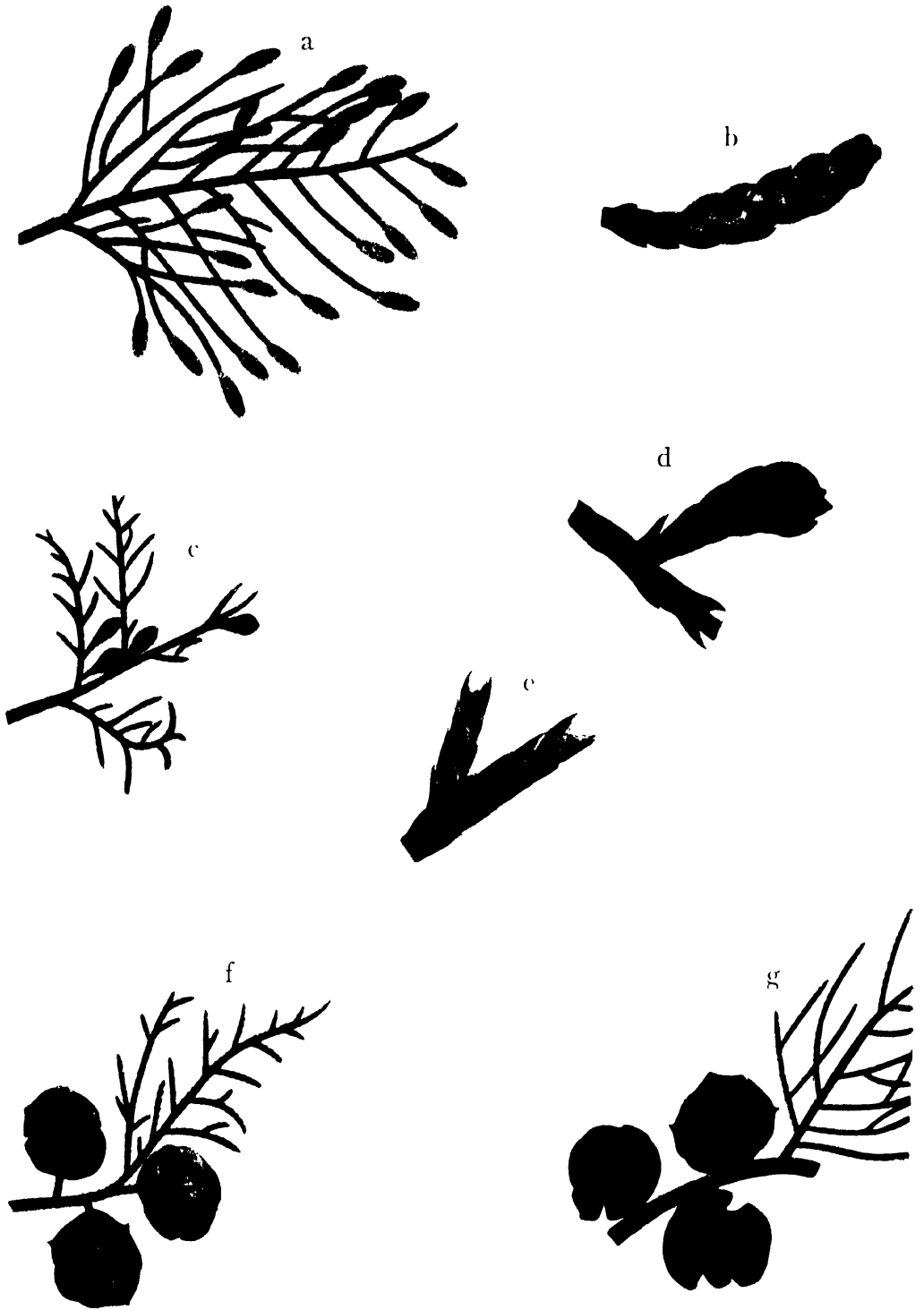


FIG. 486. *Cupressus torulosa*—FLOWERS AND FRUIT

a—Male flowers at time of ripening, January, $\times \frac{1}{4}$ b—Single male flower $\times 5$ c—Female flowers at time of fertilization, January $\times \frac{1}{4}$ d—Single female flower at time of fertilization $\times 3\frac{1}{2}$ e—Portion of branchlet showing arrangement of scales $\times 3\frac{1}{2}$ f—Full-sized cones in second year, not yet ripe, January-July $\times \frac{1}{4}$ g—Old cones remaining on tree the year after ripening $\times \frac{1}{4}$ h—Single seed $\times 2\frac{1}{2}$

temperature is probably about 90° F., the absolute minimum about 15° F., and the normal rainfall varies from about 45 to 95 in.

FLOWERING AND FRUITING. The male flowers first become visible, as small pale green dots at the ends of the branchlets, in September–October. They ripen and shed their pollen in January or early February, the trees at this time being conspicuous with their golden yellow covering of male flowers. These flowers are 0.1–0.3 in. long, yellow, with opposite decussate peltate scales, the anthers near the edge (Fig. 486, *a* and *b*).

The female flower at the time of pollination in January is a somewhat inconspicuous club-shaped structure, about 0.3 in. long, consisting of a thick quadrangular stalk covered with green imbricate scales and surmounted by the flower proper, which is about 0.2 in. long by 0.1–0.2 in. in diameter, composed of 6–10 purplish green to dark purple scales enclosing the numerous naked erect ovules. These flowers are found at the ends of the ultimate newest branchlets (Fig. 486, *c* and *d*).

After pollination the young female cones gradually change their form and colour. By May they become pale bluish green, and about 0.3 in. long. From then onwards they grow rapidly, becoming full-sized by September or October, when they are globose, about 0.5–0.6 in. in diameter, pale bluish green, covered with a glaucous bloom, with fleshy scales, green inside. The succeeding months are occupied in the gradual ripening of the seeds within the apparently fully-developed cones, and by April or sooner the seeds are quite ripe and loose within the cones, although the cone-scales are still soft and green inside, and are easily cut with a knife. The cones remain in this condition during the early part of the rainy season, and commence opening and shedding their seeds in August, continuing to do so during sunny weather until November or even December.

Thus although the seeds ripen in about a year from the time of pollination of the female flower, the cones do not open and shed the ripe seeds until one year and seven to ten months from the time of pollination. This tardy shedding of the seed, which is noticeable in other species of cypress, is interesting. Ripe seed of good quality can be readily obtained, for the purpose of sowing, by collecting the cones in June and placing them in the sun until they open.

The cones when fully developed are globose, 0.5–0.6 in. in diameter, with 8–12 thick peltate 4- to 6-sided scales, each with a small pointed process in the centre, greenish brown with a pale bluish bloom before opening, becoming brown and woody on opening (Fig. 486, *f* and *g*). The open woody cones remain some time on the tree after shedding their seed.

The seeds (Fig. 486, *h*) are compressed, with an orbicular somewhat obscure wing, 0.15–0.2 in. in diameter including the wing, light reddish brown. Many are smaller, but these are usually abortive. Each cone contains about 45–80 seeds, but a considerable proportion are infertile. About 5,000 to 6,000 good seeds weigh 1 oz. The tree begins to produce seed at an early age. In Jaunsar natural plants 5½ ft. high, and estimated to be about fifteen years old, have been observed bearing seed. At Dehra Dun planted trees have borne cones at an age of seven years, but the seed has not been tested. Good seed-years are frequent.

GERMINATION (Fig. 487, *b–e*). Epigeous. The radicle emerges from the

apex of the seed. The hypocotyl then elongates, often with slight arching, carrying above ground the testa, which falls with the expansion of the cotyledons.

THE SEEDLING (Fig. 487).

Roots : primary root long, wiry, flexuose, terete, brown ; lateral roots few to moderate in number in first season, afterwards more numerous, fibrous. *Hypocotyl* distinct from the root, 0.7–1.4 in. long, cylindrical, soon becoming woody, red turning brown. *Cotyledons* two, sessile, 0.3–0.4 in. by 0.04–0.05 in., linear, acute, entire. *Stem* erect, terete, green, glabrous ; internodes in first season 0.1–0.2 in. long ; side branches commence forming in first season. *Leaves* : primordial leaves acicular, 0.25–0.4 in. long, in decussate whorls of 4, sometimes 3 ; triangular scale-like adult leaves usually begin to be formed in the third year.

The growth of the seedling during the first season is slow, a height of only about 1–3 in. being ordinarily attained. Subsequent growth is faster. Seedlings raised at Dehra Dun showed the following growth from the second to the sixth year :

End of season.	2nd.	3rd.	4th.	5th.	6th.
Height . . .	7–12 in.	1 ft. 6 in.– 2 ft. 1 in.	3 ft. 3 in.– 5 ft. 5 in.	5 ft. 0 in.– 7 ft. 6 in.	7 ft. 2 in.– 10 ft. 11 in.
Girth . . .	..	..	..	..	3½–5½ in.

This growth is faster than is ordinarily the case at the cooler elevations where the tree is found naturally ; here an average height of about 2 ft. is ordinarily attained in four years in the case of artificially raised seedlings. The seedling requires a porous soil, rapidly damping off in soil which is stiff and saturated with moisture.

SILVICULTURAL CHARACTERS. The cypress is somewhat similar to the deodar in its light requirements, if anything standing rather more shade. In India it is frost-hardy ; on the plains it remained unaffected by the severe frost of 1905. In Britain, however, it is not hardy, and does not grow well except in places where severe frosts are absent. In the Himalaya it is subject to snow-break : the snow lodges in quantity among the ascending branches near the tops of the trees, and the tops are often broken off. A fungus, *Gymnosporangium Cunninghamianum*, Baryl., attacks the branches of the cypress, appearing in wet weather in the form of yellow gelatinous masses. The alternate generation, the aecidial form, is on the leaves of *Pyrus Pashia*.

NATURAL REPRODUCTION. Under natural conditions the seed, which falls from August to December, remains on the ground until the beginning of the following rainy season, about July, when germination commences ; heavy rain may stimulate germination earlier, but if a spell of dry, hot weather ensues the seedlings tend to die of drought if in an exposed position. Natural seedlings spring up most readily on bare, loose ground such as that formed by the accumulation of debris at the bases of cliffs through the disintegration of the rocks, or by small landslips. Natural seedlings have been found springing up readily on recently abandoned fields. On loose, fresh soil the taproot develops quickly and soon establishes itself, but under less favourable conditions the seedling requires such protection from the sun as is afforded by rocks, shrubs, or tussocks of grass. Natural seedlings are sometimes found growing out of the crevices of rocks.

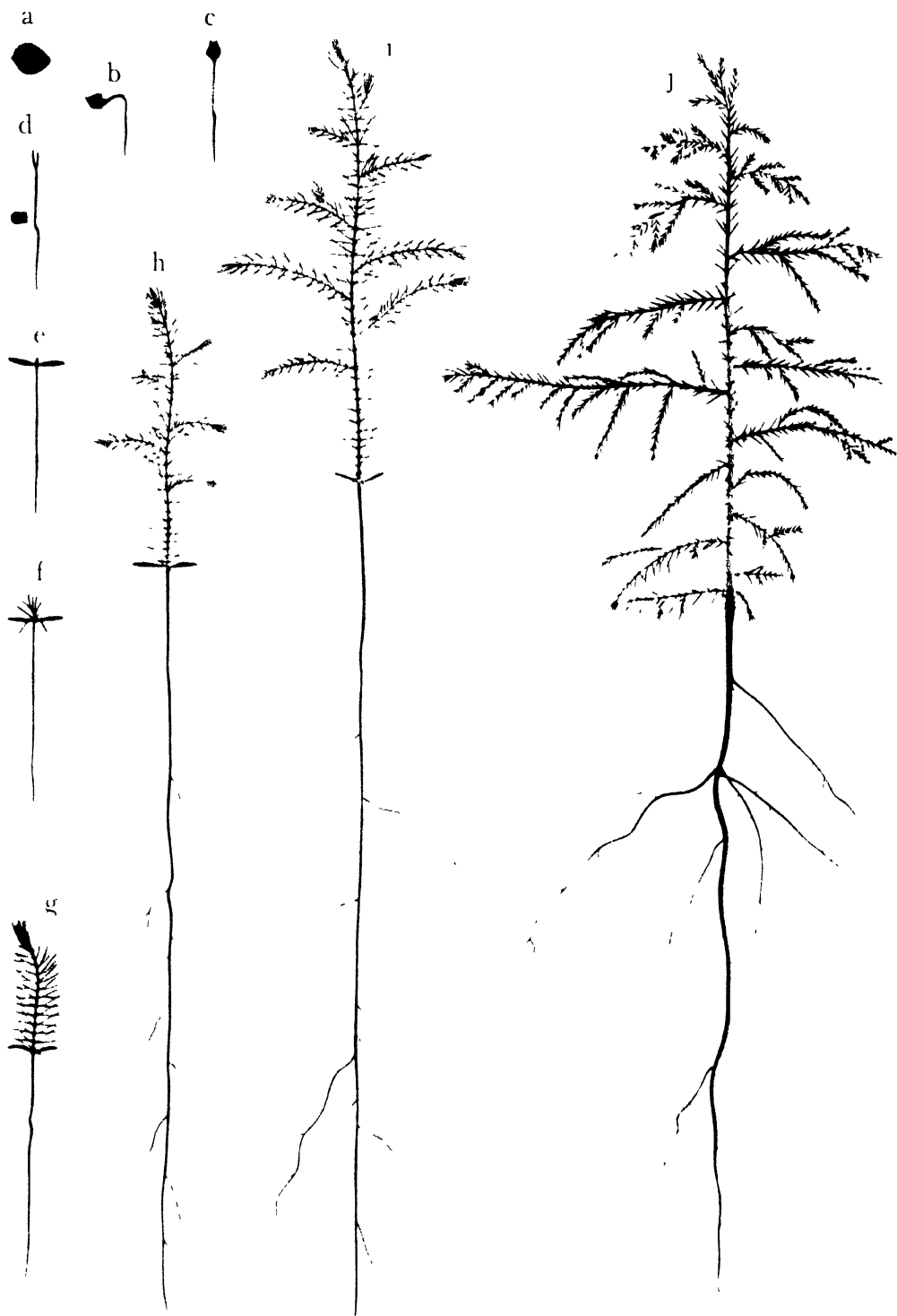


FIG. 487. *Cupressus torulosa*—SEEDLING $\times \frac{1}{2}$

a—Seed $\times 1\frac{1}{2}$ b - e—Germination stages $\times \frac{1}{2}$ f - i—Development of seedling to end of first season $\times \frac{1}{2}$
j—Seedling in middle of second season $\times \frac{1}{2}$

ARTIFICIAL REPRODUCTION. Mathura Prasad Bhola ¹ found from experiments at Pauri, Garhwal, in 1917, that in order to promote early germination the best time to sow seed, whether direct or in the nursery, is soon after the break in the monsoon rains, when germination takes place in two to three weeks. In Jaunsar seedlings are successfully raised by sowing in boxes either in June or in November; in the latter case germination commences about May of the following year. Boxes are found preferable to seed-beds, but in either case light porous soil is necessary, and protection from heavy rain is required. The seedlings are pricked out in the nursery when large enough, and finally planted out in the third season, small plants being kept for another year. Direct sowings are not likely to be successful, owing to the small size of the seed and its poor germinative power.

Seedlings have been raised successfully at Dehra Dun by sowing in boxes in November or December, keeping the boxes under shade and watering regularly but sparingly; germination began in March and continued till July. The seedlings were pricked out in beds the following year and planted out successfully during the rainy season the year after.

SILVICULTURAL TREATMENT. The cypress is so restricted in its distribution that it is seldom possible to work it as a crop by itself, and in practice it has usually been worked as an auxiliary species to deodar. Possibly it might be worked under regeneration fellings in the few places where it occurs in sufficient quantity, but of this we have no experience. It has been planted to some extent in the Himalaya, for instance in Jaunsar in mixture with deodar. Where its cultivation on any scale is desired clear-felling and artificial reproduction would be the only feasible method.

RATE OF GROWTH. In its natural region the growth of the cypress is only moderate, but at Dehra Dun it is fast, at all events in youth. In the mixed plantations of deodar and cypress in Jaunsar the former usually outgrows the latter. The following are measurements of three cross-sections at Dehra Dun :

(1)	Girth 2 ft. 3 in.	Age (from annual rings) 12 years :	mean annual girth increment 2.25 in.
(2)	„ 3 ft. 11 in.	„ „ 76 „ „ „ „	0.62 in.
(3)	„ 5 ft. 10 in.	„ „ 59 „ „ „ „	1.19 in.

No. (1) was from a tree grown at Dehra Dun.

2. *Cupressus sempervirens*, Linn. Mediterranean cypress. Vern. Sara, Hind.

A large evergreen tree, often with a fluted stem. Bark thin, smooth or with slight longitudinal fissures, greyish brown, peeling off in thin strips which often run spirally up the stem. There are two well-marked varieties of this tree : (1) var. *horizontalis*, Gordon (*Cupressus horizontalis*, Miller), with spreading branches, the common wild form; (2) var. *stricta*, Aiton (var. *pyramidalis*, Nyman; var. *fastigiata*, Hansen), with erect branches running more or less parallel to the stem, giving the tree a narrow pyramidal shape; the form most commonly met with in cultivation.

The tree in its wild form (var. *horizontalis*) is indigenous to the mountains of northern Persia, to Syria, Asia Minor, Crete, and Cyprus. It is extensively cultivated, especially the fastigate variety, throughout the Mediterranean

¹ Ind. Forester, xlv (1918), p. 175.

region as well as in many other parts of the world, including Britain, where, however, it does not stand severe frost. This variety is largely cultivated in India on the plains, in the outer Himalaya, and in Kashmir. The spreading variety is grown in India, particularly in the hills, to a lesser extent.

The cones are larger than those of *C. torulosa*, sub-globose or ovoid, 0.8–1.2 in. long. The flowers appear from February to April, the seeds becoming ripe early the following year, though the cones do not open until the following autumn. The seeds have a very narrow wing. They keep fertile a long time; Elwes¹ records a case of seeds collected at Scutari in 1884 which remained fertile for eleven years. Seedlings can be best raised in boxes, from which they are pricked out when a few inches high and transplanted when three or four years old. The tree requires well-drained soil.

3. *Cupressus funebris*, Endl. Weeping cypress.

A large evergreen tree with ascending or horizontal branches and long, slender, pendulous branchlets. Bark smooth, brown, fibrous. A native of central China. Cultivated in India, chiefly near temples and monasteries in the eastern Himalaya. There are several trees at Dehra Dun, growing fairly well. Gamble mentions that trees planted in 1886 in the Dhobijhora plantation near Kurseong had a girth of over 4 ft. in 1899. Cones globose, 0.3–0.5 in. in diameter.

4. *Cupressus macrocarpa*, Hartweg. Monterey cypress.

A large evergreen tree with thick, scaly bark. In youth it has a narrow, pyramidal crown, which becomes broad and flattened in old trees. Under cultivation it tends to produce a fastigate and a spreading form, like *C. sempervirens*. This species has a very restricted distribution, near Monterey along the sea-coast in California and on the island of Guadalupe. It is grown in the Nilgiris. There is a small plantation near Ootacamund, which gives an extremely dense shade. Cones ellipsoidal, 1–1.5 in. long by 0.75 in. in diameter.

Elwes² says it seems indifferent to the nature of the soil in a well drained situation, and grows well on limestone, sand, and peat. He adds that it is easy to raise from seed, and grows faster than any other cypress when young, but that its timber appears to be so coarse and knotty that it is not likely to be of any economic value; it is, however, a good tree for ornamental purposes, stands clipping well, and is very useful for making hedges, growing much faster for this purpose than the yew. It has great power of withstanding storms and saline winds on the sea-coast, and in suitable climates it is a useful tree for planting for shelter-belts in coastal regions.

5. *Cupressus lusitanica*, Miller. Syn. *C. glauca*, Lam. Mexican cypress, Goa cypress.

A large evergreen tree with widely spreading branches and pendulous branchlets. Bark reddish brown, exfoliating longitudinally in long, thin strips. Leaves bluish, ovate acuminate, slightly free at the apex, not so closely adpressed as in *C. torulosa*. Cones globose, about 0.5 in. in diameter, dark reddish brown, covered with a glaucous bloom. Possibly a native of Mexico, where it occurs at 4,000–10,000 ft., chiefly near streams and on moist slopes. It is cultivated in Western India on deep, rich soil; it does not thrive

¹ Elwes and Henry, *op. cit.*, v. 1156.

² Elwes and Henry, *op. cit.*, v. 1168.

below the *ghats*. It is known there and elsewhere as the Goa cypress, and may have been introduced by the Portuguese, as it is commonly grown in Portugal.

6. *Cupressus Lawsoniana*, Murray. Lawson's cypress.

A large evergreen tree with very thick reddish brown spongy bark forming ridges covered with small scales; bark on young stems thin, with narrow longitudinal cracks. Leaves acute, usually with whitish streaks on the under surface. Male flowers crimson. Cones 0.35 in. in diameter, reddish brown, covered with a glaucous bloom. A very variable tree under cultivation, fastigate, spreading, pendulous, dwarf and coloured varieties being known. A native of south-west Oregon and north-west California, in an equable, moist climate, at elevations chiefly below 3,000 ft., occasionally up to 5,000 ft. A shade-bearing species, demanding shade and moisture when young, and requiring to be planted close to produce a clean bole. In Britain it has proved not only very hardy, but also decidedly accommodating as regards soil. It is easily raised from seed sown in boxes, which should be kept shaded; it grows also from cuttings. Its timber is highly valued in Oregon and California. The tree is occasionally planted in Indian hill stations, as at Darjeeling, and deserves further attention. It may prove a useful species for underplanting deciduous broad-leaved trees at suitable elevations. The growth is fairly fast, and owing to the close spacing which the tree will stand, the volume per acre should be comparatively high.

8. *JUNIPERUS*, Linn.

The junipers are evergreen shrubs or trees, the leaves on young plants acicular and spreading, those on older plants either acicular or adpressed and scale-like. Flowers monoecious or dioecious. Male flowers in small catkins; female flowers composed of a few pointed scales bearing one or two ovules at their base or alternate with them. Cone succulent and berry-like, composed of the united fleshy scales enclosing one or more seeds, in Indian species ripening in the second (or third?) year. Four Indian species, all at the higher elevations and ascending to the limit of tree-growth; they grow in dry, barren regions with scanty rainfall, and exhibit marked xerophilous tendencies. Economically some of the junipers are important as furnishing pencil cedar wood, the two most important being *J. virginiana*, Linn., of North America, and *J. bermudiana*, Linn., of the West Indies. Two of the Indian species, *J. recurva*, Ham., and *J. macropoda*, Boiss., have been tried by a Calcutta firm and found suitable, but it is doubtful if they can be obtained readily enough and in sufficient quantity to support a regular industry. The latter is found in some quantity in Baluchistan, but the supply is required for local use.

Species 1. *J. macropoda*, Boiss.; 2. *J. Wallichiana*, Hook. f. and Thoms.; 3. *J. communis*, Linn.; 4. *J. recurva*, Buch. Ham.

1. *Juniperus macropoda*, Boiss. Syn. *J. excelsa*, Brandis. Himalayan pencil cedar. Vern. *Appurz*, *ghushki*, Baluch.; *Obusht*, Pushtu; *Shûr*, *chalai*, *dhup*, W. Him.

A moderate-sized tree with light open foliage. Leaves dimorphous, the acicular leaves opposite or in whorls of three, the scale-like leaves usually opposite, closely adpressed. Bark reddish brown in young trees, reddish

brown to grey in older trees, exfoliating in long fibrous strips. The bark at the base of old trees is of great thickness, and is removed for roofing huts. Wood moderately hard, fragrant, used for building, utensils, and other purposes, and for fuel and charcoal. It has been pronounced suitable for pencil manufacture.

The tree does not ordinarily attain a height of more than 50 ft., and seldom reaches a height of 80 ft., but Lala Mul Raj mentions having met with an exceptionally tall tree 100 ft. in height in the Chotair forest, Baluchistan. He has supplied me with the following measurements made in Baluchistan in 1916 :

Gohar forest	(1)	Height 80 ft.,	girth 15 ft.
	(2)	.. 75 ft.,	.. 14½ ft.
Batsirgi forest		.. 40 ft.,	.. 18 ft.
Chotair forest	(1)	.. 100 ft.,	.. 11½ ft.
	(2)	.. 65 ft.,	.. 10 ft.
	(3)	.. 75 ft.,	.. 12 ft.
Shaidan forest		.. 57 ft.,	.. 21 ft. near base ; branched at 2½ ft. from ground.

Brandis mentions a tree 33½ ft. in girth in Lahoul. The trunk is often crooked and gnarled, and sometimes exhibits 'twisted fibre', the twist in some cases running in one direction and in others in the opposite direction. The tree rarely forms a clean bole, but usually branches to the base, the lowest branches being often buried in leaf débris near the trunk, and their extreme ends taking an upward turn, giving them the appearance of young trees surrounding the old one.¹

DISTRIBUTION AND HABITAT. Inner arid ranges of the Himalaya from Nepal westwards, at 5,000–14,000 ft., growing more or less gregariously in open crops or in the form of scattered trees on dry rocky or stony ground in regions of scanty rainfall ; Chitral, above 8,000 ft. ; Kurram valley, common at 9,000 ft. ; Baluchistan. It is cultivated at Saharanpur on the plains of northern India.

The most important juniper tracts occur in Baluchistan, where they are estimated to cover a total area of not less than 1,500 square miles, including the forests of the Kalat State. The tree occurs at elevations of 6,500 to 10,000 ft., but is commonest between 7,500 and 9,000 ft. It is usually found more or less gregariously in open forest, frequently with an underwood of *Prunus eburnea*, *Caragana Gerardiana*, *Fraxinus xanthoxyloides*, *Pistacia mutica*, and *P. Khinjak*. Only where the conditions are specially favourable, that is, in sheltered situations with a moderate amount of moisture in the soil, does the juniper crop tend to become fairly dense. The prevailing rock in the Baluchistan juniper tracts is limestone, though shale, grey sandstone, conglomerate, and other rocks occur locally. Topographically the country consists of barren mountain ridges separated by valleys or plateaux where the soil is deep and fertile, consisting of the accumulations of the detritus from the ridges, and where the juniper attains a large size and is well shaped. It occurs sometimes on bare rocks, but here it is stunted. The moister valleys are occupied by ash and other broad-leaved species. Fig. 488 shows a typical

¹ J. H. Lace, Journ. Linn. Soc., xxviii. 307.



FIG. 488 Forest of *Juniperus macrospora*, Baluchistan



FIG. 489. Plantation of *Callitris rhomboidea*, Ootacamund.



FIG. 490. Interior of *Callitris rhomboidea* plantation, showing dense natural reproduction, Ootacamund.

juniper tract in Baluchistan. Climatic statistics within the juniper regions are scanty. Generally speaking the rainfall probably never exceeds 12 in., while the minimum temperature may fall to well below zero Fahr.; in the winter the snowfall may be considerable.

FLOWERING AND FRUITING. The flowers appear in the spring and the fruits ripen in September–October in the second year. Male flowers 0.1–0.2 in. long. Berries sub-globose, 0.25–0.35 in. in diameter, bluish black when ripe, 2- to 5-seeded. Some seed is produced as a rule every year, but good seed-years occur at less frequent intervals. In Baluchistan the seeds appear to be disseminated chiefly by the agency of a bird named by the Pathans *obusht khawarak* (juniper eater), which feeds on the ripe fruits.

SILVICULTURAL CHARACTERS. The tree has a strong spreading root-system, particularly on dry rocky ground, where the roots spread far in search of moisture; it is therefore wind-firm, though it becomes gnarled and stunted in exposed situations. It is hardy both to drought and to frost, enduring very low temperatures. In unprotected tracts it suffers much from the hand of man, by lopping and by stripping of the bark. The custom, apparently commoner at one time than it is now, of setting fire to standing trees for the protection of flocks from beasts of prey at night, has been responsible for the destruction of large numbers of trees in Baluchistan. Owing to the scantiness of the grass and undergrowth in many of the juniper forests the trees are not exposed to much damage from ordinary fires, but injury by grazing is accentuated from the same cause, for which reason grazing is excluded from the state forests of Baluchistan wherever conditions permit. Rats and porcupines do a certain amount of injury to young plants. Trees are frequently struck by lightning in the juniper forests, and may be completely destroyed from this cause.

NATURAL REPRODUCTION. Seedlings appear naturally to a varying extent, but the great majority perish, probably from drought. A heavy snowfall has been found to assist reproduction by increasing the moisture in the soil, while in fairly moist, sheltered situations seedlings occasionally spring up in some quantity. Protection from fire and grazing is necessary for the successful establishment of natural reproduction, which, however, is at the best a very slow process.

SILVICULTURAL TREATMENT. At present the working of the state juniper forests of Baluchistan consists in removing dead trees and only such living trees as are necessary to supply right-holders when dead trees are not available.

RATE OF GROWTH. The annual rings are distinctly marked by a narrow dark line. The rate of growth is very slow. Lala Mul Raj informs me that in 1915 he made ring-countings on eight stumps on deep fertile soil in a valley, and found the average growth to be 20.38 rings per inch of radius, giving a mean annual girth increment of 0.3 in., while a slow-grown specimen in the Quetta sale dépôt showed 92 rings per inch of radius, giving a mean annual girth increment of 0.07 in. Mr. Lace, by ring-countings on five stumps, obtained an average of 26.46 rings per inch of radius, giving a mean annual girth increment of 0.23 in. The sections recorded by Stewart gave 24, 40, and 44 rings per inch of radius, giving a mean annual girth increment of 0.26, 0.15, and 0.14 in. respectively.

Thus the mean annual girth increment varies from under 0.1 to 0.3 in., and probably exceeds the latter figure only under more than ordinarily favourable conditions. A tree may therefore be expected as a rule to attain a girth of 6 ft. in anything from 240 to 720 years.

2. *Juniperus Wallichiana*, Hook. f. and Thoms. Syn. *J. pseudo-sabina*, Fisch. and Mey. Black juniper. Vern. *Bhil*, Hind.

An evergreen tree with spreading branches and bushy foliage, attaining a height of 60 ft. in Sikkim; in the western Himalaya only a shrub. Leaves dimorphous, both acicular and scale-like, the latter opposite decussate in four rows, making the branchlets quadrangular. Himalaya from the Indus to Bhutan, at 9,000–15,000 ft.; in the north-west a large gregarious shrub covering extensive areas at the limit of tree vegetation, associated with *Betula utilis*. Flowers April–May; fruits August (Brandis). Berries ovoid, acute, 0.25–0.5 in. long, blue when ripe, one-seeded.

3. *Juniperus communis*, Linn. Common juniper. Vern. *Páma*, *betar*, *thelu*, W. Him.

An evergreen shrub, sometimes a small tree, procumbent at high elevations. Leaves all acicular, usually 0.4–0.6 in. long, in whorls of three. Bark reddish brown, smooth, peeling off in papery sheets.

A widely distributed plant, occurring throughout the northern and central part of Europe, at the higher elevations of the Mediterranean region, and eastward through Siberia, Persia, Afghanistan, Kurram valley at 11,000–13,000 ft., and the western Himalaya at 5,500–14,000 ft., extending eastward to Garhwal and Kumaun, where it occurs only at the higher elevations. In Europe it is frequently gregarious and is often abundant on heath land, on rocky mountain slopes, or on peat overlying a sandy subsoil. The flowers appear in March–April, and the fruit, a sub-globose, bluish black, usually three-seeded berry, ripens in August–September of the second year (Brandis). In Europe the fruits are used in the manufacture of gin.

Elwes¹ says the seeds lie for one year before germinating, even when freshly sown, and that they keep for some years in the berry without losing their vitality. Under natural conditions the seeds are freely spread by birds, which devour the fruits.

4. *Juniperus recurva*, Buch.-Ham. Weeping blue juniper. Vern. *Betar*, *thelu*, *guggal*, W. Him.

An evergreen straggling shrub or small graceful tree with curved or drooping branches and glaucous blue foliage. Leaves all acicular, decurrent, densely imbricated in whorls of three, turning brown after three or four years and persisting for a time after that.

Inner ranges of the Himalaya, at 7,500–15,000 ft., extending east to Bhutan and west to Afghanistan. The plant is very gregarious, often extending over large areas pure or mixed with *J. communis*. In the west it is represented by the procumbent variety (var. *squamata*, Parlat.; *J. squamata*, Buch.-Ham.), the stems of which creep over the ground, rooting freely and sending up numerous short, erect branches which form dense thickets. This procumbent variety is frequently grown as a low dense shrubby border in gardens at low elevations. It thrives at Dehra Dun (2,000 ft.) and grows even on the

¹ Elwes and Henry, *op. cit.*, vi. 1405.

plains. It is propagated by taking cuttings of the prostrate stems with the bushy foliage attached, planting them in nursery beds and watering them regularly until well rooted, after which they are planted out early in the rainy season.

Flowers chiefly June–July; fruits July–October of the second year (Brandis). Berries ovoid, 0.3–0.5 in. long, one-seeded.

9. CRYPTOMERIA, Don.

A genus of eastern Asia, containing only one species.

Cryptomeria japonica, Don.

A large evergreen tree attaining in Japan a height of 150 ft. or more and a girth of 20 to 25 ft. Trunk with a broad base, tapering upwards. Bark reddish brown, peeling off in long strips. Needles awl-shaped, quadrangular, with decurrent bases, arranged spirally in five ranks. Flowers monoecious. Male flowers clustered at the ends of the branchlets; female flowers at the ends of the branchlets, globose, cone-like, covered with small awl-shaped leaves. Cones woody, globose, brown, 0.7–0.8 in. in diameter, with scales bearing acuminate bracts partly adnate to them. Seeds 0.15–0.25 in. long, compressed, angular. The growth of the shoot is often continued through the cone. Wood soft, fragrant, with a reddish brown heart-wood. Gamble says it makes excellent tea-boxes, and as it grows rapidly it is worth cultivating for this purpose and for box-planking generally. In Japan it is extensively used, particularly for building, staves, tubs, and casks.

The tree is indigenous to China, as far as is known only in the mountains of the Chekiang and Fokien provinces, and to Japan, also in mountainous country, and is much planted in both countries.

Seeds were first brought to India in 1844 by Mr. Fortune on his first mission to China for tea seed, and since then the tree has been planted to a considerable extent in suitable localities. In the Darjeeling hills it has been successfully grown at elevations varying from 3,000 to 7,000 ft., but appears to thrive best between 4,000 and 6,000 ft. At 7,500 ft. on Jalapahar the trees are stunted and the growth is slow. In the neighbourhood of Shillong it thrives between 4,000 and 6,000 ft. on moist soil, growing far more rapidly than the indigenous pine (*Pinus Khasya*). It is planted to a certain extent in the western Himalaya, in Simla and other hill stations, but does not seem to grow so well as it does farther east in a moister climate.

In the Darjeeling hills the cones ripen in July–August at the lower elevations and somewhat later at the higher elevations. Seeds sown in the winter germinate as a rule in April or May. Experience in the Darjeeling hills has shown that the seed-beds require to be sheltered under mats until the seedlings are about 6 in. high, when the mats are removed for two or three weeks in order to harden the young plants before transplanting. It is usual to prick out the seedlings in the nursery and to plant them out when about 1½ to 2 ft. high. Young plants are said not to be eaten by cattle; they succeed well in the open or under very slight shelter. The trees seed freely in the Darjeeling hills. Gamble says that the trees in a plantation formed about 1866 at Dhobijhora near Kurseong had attained a girth of 43 in. in 1899, that is, at an age

of about thirty-five years from seed. Elwes¹ gives the following account of the planting of cryptomeria in Japan :

'The trees are planted out at three years old after being twice transplanted in the nursery, where they are raised from seed and kept shaded during the first year. This, at least, is the rule in the Kisogawa district, though I was told that in the south cryptomerias are more cheaply and quickly raised from cuttings, and that these produce as good trees as seedlings.

'About 4,000 per acre are usually planted, and weeded once or twice a year for three years, when they suppress the weeds by their shade. The plantations grow very fast, and are pruned from the eighth to the twenty-third year after planting out. Thinning is done at the earliest at twelve years, and the thinnings form such a profitable source of revenue that income is probably returned quicker by such a cryptomeria plantation than by any other tree. The final felling takes place at about 120 years old, when as many as 180 trees, containing 15,000 cubic feet, may be found on an acre. The previous thinnings are estimated at 16,000 cubic ft., making the total product per acre in 120 years over 30,000 ft. This result, which appears astonishing, is perhaps exceptional, but all the plantations I saw gave evidence of extremely rapid growth, and showed a larger proportion of clean useful poles and timber than any plantations I have seen in other countries.'

The method of treatment commonly followed in Japan is that of clear-felling followed by replanting.

Measurements made in 1917 by Mr. E. Marsden in four sample plots in the Darjeeling hills and one at Ootacamund in the Nilgiris gave the following results :

Cryptomeria japonica : measurements in sample plots.

Serial No.	Locality.	Age. years.	Number of stems per acre.	Mean girth. in.	Mean height. ft.	Timber over		Total.	Num-ber of stems.	Timber over		Total.	Rem
						24 in. in girth.	Small-wood.			24 in. in girth.	Small-wood.		
						cub. ft.	cub. ft.	cub. ft.		cub. ft.	cub. ft.	cub. ft.	
1	Darjeeling	22	296	36.4	63	3,577	802	4,379	408	467	1,241	2,208	
2	"	24	119	43.7	64	2,074	261	2,335	..	..	..	..	Heavily ned at vals: o not rec d
3	"	28	104	44.2	76	2,951	266	3,217	..	..	..	..	Unthin d
4	"	50	157	84.1	78	12,710	202	12,912	..	..	..	..	
5	Ootacamund	31	322	40.0	66	4,114	865	4,979	..	..	..	..	

10. CALLITRIS, Vent.

A genus of the tribe Cupressineae, the Australian species of which are usually known as 'cypress pine'. No species indigenous to India; one introduced.

Callitris rhomboidea, Br. Syn. *Frenela rhomboidea*, Endl. Oyster Bay pine.

A moderate-sized tree with feathery cypress-like foliage, sometimes attaining a height of 70 ft., but usually a good deal smaller. Indigenous to the rocky coastal regions of New South Wales, Victoria, South Australia, and Tasmania, seldom growing far inland. The tree was introduced into the Nilgiris in the years 1885 to 1891 by Mr. Gamble, who planted it extensively

¹ Elwes and Henry, *op. cit.*, i. 135.

about Ootacamund and Coonoor ; the plantation at Aramby is a feature of the environs of Ootacamund. The wood is soft, easily worked and very resinous, and appears to be used in Australia mainly for cheap furniture, planking, and weather-boarding. In the Nilgiris it has been found to be very soft and full of turpentine, and there is little demand for a wood of this type. It gives an excellent firewood of the fragrant resinous kind.

In the Nilgiris the tree has been found to grow best in pure plantations ; mixed with pines or *Cryptomeria* it has been found to get the upper hand, and mixed with cypress the latter suppresses it. It requires a sheltered situation, as it is liable to be broken by wind ; light but frequent thinnings tend to produce tolerably wind-firm trees. One of its most marked characteristics is the extraordinary profusion with which it regenerates naturally from seed wherever the canopy is slightly broken and light is admitted. Fig. 489 gives a view of a portion of the Aramby plantation, along the edge of which a dense line of natural reproduction up to 10 ft. high is seen. Fig. 490 shows a portion of the interior of the same plantation, in which the ground is covered with a dense crop of natural seedlings up to 3 or 4 ft. high. These seedlings frequently bear cones when only 2 or 3 ft. high.

In the Nilgiris the growth is somewhat slow but very regular. • The rings, which have been ascertained to be annual, are quite distinct. The following table, based on numerous measurements, gives the average rate of growth and volume production per tree : ¹

Callitris rhomboidea : rate of growth and volume production, Nilgiris.

Age.	Mean height.	Mean diameter.	Corresponding girth.	Mean volume per tree.
years.	ft.	in.	in.	cub. ft.
5	10.5	1.05	3.1	..
10	21	2.55	8.0	..
15	30	4.15	13.0	0.60
20	38.5	5.48	17.2	1.90
25	45.5	6.55	20.6	3.75
30	51.5	7.40	23.2	5.80
32	54	7.80	24.5	6.70

11. PODOCARPUS, L'Hérit.

Trees or shrubs, usually with linear lanceolate or elliptical lanceolate leaves ; flowers dioecious, rarely monoecious. Three Indian species.

Species 1. *P. neriifolia*, Don ; 2. *P. latifolia*, Wall.

1. *Podocarpus neriifolia*, Don. Syn. *Nageia bracteata*, Kurz. Vern. *Gunsi*, Nep. ; *Jinari*, Cachar ; *Thimin*, Burm.

A large evergreen tree with whorled branches and linear coriaceous leaves 5–10 in. long. Bark greyish brown, thin, fibrous. Wood yellowish, even grained, of good quality, used for general carpentry.

The tree occurs up to 3,000 ft. in the eastern Himalaya from Nepal eastwards in the evergreen forests of the outer hills, Assam, Khasi hills, Chittagong, the tropical forests of Martaban and Tenasserim, and the Andamans. In the Andamans it is sometimes common on the higher hills in evergreen forest on

¹ Working Plan for the Nilgiri Plantations, S. Cox, 1914.

serpentine and micaceous sandstone along with *Mesua ferrea* and other trees.

Gamble gives the rate of growth at fifteen rings per inch of radius, representing a mean annual girth increment of 0.42 in., which is slow.

2. *Podocarpus latifolia*, Wall. Syn. *Nageia latifolia*, Gordon.

An evergreen tree of Assam, Martaban, and Tenasserim, and the Tinnevely *ghats* at 3,000–5,000 ft. The only conifer of the Indian Peninsula.

12. TAXUS, Linn.

This genus consists of one species, *T. baccata*, Linn., of which there are several varieties which have been described as species, but are now usually recognized as geographical forms. The genus differs from all other conifers in the ariloid fleshy fruit.

Taxus baccata, Linn. Yew. Vern. *Barma*, *barmi*, *thunu*, *thuner*, W. Him.

An evergreen shrub or tree, sometimes attaining large dimensions in the Himalaya, usually much branched, with spreading branches and dense foliage. Needles distichous, 1–1.5 in. long, flat, dark green and shining above, light green below. Flowers dioecious, rarely monoecious. Bark thin, reddish brown, scaly. Wood hard, close and even grained, requiring long seasoning, tough and elastic. In England the wood is used for bows for archery, and a few years ago a small consignment of Himalayan wood was sent home for the purpose, and was well reported on.

In the Himalaya the yew sometimes reaches large dimensions. In Jaunsar girths of 9 ft. 1 in., 11 ft. 2 in., 11 ft. 9 in., 12 ft. 6 in., and 14 ft. 6 in. have been recorded. According to Brandis, Madden has recorded a tree at Gangutri 100 ft. high and 15 ft. in girth. Mr. Gamble¹ measured two trees in the Darjeeling hills, one 20 ft. in girth, broken at the top, the other 16 ft. in girth with a straight cylindrical stem 30 ft. high. In Hazara, where large trees are common, I have measured trees up to 14 ft. 3 in. in girth; the tallest tree found was 60 ft. high. Large trees are almost invariably hollow.

DISTRIBUTION AND HABITAT. The yew is widely distributed through the northern hemisphere. In India it is indigenous to the Himalaya at 6,000–11,000 ft., but chiefly above 7,000 ft., the Khasi hills, and the hills of the Ruby Mines district of Upper Burma at 5,000 ft. and over. It is particularly common in the forests of Hazara, where it reaches a large size. It is found as a rule in moist, shady places, often as an underwood to broad-leaved species or other conifers. Fig. 185 shows it growing under *Prunus Padus*.

LEAF-SHEDDING, FLOWERING, AND FRUITING. In the Himalaya the needles are shed chiefly in May and June. The flowers appear from March to May, and the fruits ripen from September to November. The male flowers consist of a globose head of stamens on a common stalk, and the female flowers of a single erect ovule surrounded by a disk, on a peduncle covered with imbricate scales. The fruit consists of a solitary seed more than half enclosed in a red juicy arillus formed of the enlarged disk. The seed has a white albumen and a minute embryo. Cotyledons two in number.

SILVICULTURAL CHARACTERS. The yew is a pronounced shade-bearer,

¹ Ind. Forester, i (1875–6), p. 97.

reproducing and growing well under fairly dense shade. The leaves contain an alkaloid poison which appears to vary in virulence under different conditions, but if taken in sufficient quantity is fatal to man and to live stock. In Europe browsing animals have been known to die of the effects of yew poisoning if the leaves are devoured in any quantity. In the Himalaya, animals appear to avoid browsing on the tree. Nevertheless in parts of Hazara, particularly in the Siran and Kagan valleys, the yew is extensively lopped for cattle fodder, perhaps more so than any other conifer, and trees are frequently killed by repeated lopping.

ARTIFICIAL REPRODUCTION. The yew can best be raised from seed, but varieties are propagated by cuttings planted in sandy soil and kept under shade until they are well rooted. Seed usually takes a long time to germinate, and the growth of the seedling is very slow. The seedlings bear transplanting well.

RATE OF GROWTH. The growth is very slow, and the tree lives to a great age. Gamble's specimens varied from 12 to 44 rings per inch of radius, giving a mean annual girth increment of 0.14 to 0.52 in. Brandis gives 20 to 32 rings per inch of radius, representing a mean annual girth increment of 0.19 to 0.31 in. A cross-section in the silvicultural museum at Dehra Dun showed 133 rings for a girth of 2 ft. 9 in., giving a mean annual girth increment of 0.25 in.

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PRINTED IN ENGLAND
AT THE OXFORD UNIVERSITY PRESS

